Docket No. 50699/11 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Application of	:	Customer No.: 1912
Pedro M. Buarque de Macedo	:	Confirmation No.: 8891
Application No.: 10/625,102	:	Tech Center Art Unit: 3637
Filed: July 22, 2003	:	Examiner: Michael Safavi
For: Prestressed, Strong Foam Glass Tiles	:	

APPEAL BRIEF

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Appeal Brief is submitted in support of the Notice of Appeal filed on September 3, 2009, wherein Appellant appeals from the Primary Examiner's final rejections of Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 set forth in his Office Action dated March 4, 2009 ("the March 4, 2009 Office Action") in connection with the above-identified application.[1]

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1 Appellant's September 3, 2009 Notice of Appeal reinstated an appeal based on the previous Notice of Appeal filed on November 28, 2007 (which, in turn, reinstated an appeal based on the Notice of Appeal filed on December 22, 2006). In response to Appellant's Appeal Brief filed on March 13, 2008 in support of the November 28, 2007 Notice of Appeal, the Examiner reopened the prosecution by adding a new ground of rejection based on U.S. Patent No. 3,811,851 to MacKenzie ("MacKenzie '") in a non-final Office Action of July 11, 2008. In the subsequent Supplemental Office Action of August 21, 2008, the Examiner withdrew the claim rejection based on U.S. Patent No. 4,450,656 to Lagendijk ("Lagendijk"), which was one of the prior art the Examiner relied on in his prior final rejection. As a result of Appellant's Request for Reconsideration filed without any claim amendment on November 21, 2008, the Examiner ultimately withdrew the newly added ground of rejection based on MacKenzie. However, the

Examiner continued to reject all of the pending claims in the Final Office Action mailed on March 4, 2009 based on combinations of the eight remaining prior art references he had relied on in his prior final rejection. Despite Appellant's efforts to explain the patentability of the pending claims over the prior art during the personal interview with the Examiner on July 8, 2009, the Examiner still maintains the final rejection and suggests that Appellant pursue the appeals process. Appellant's September 3, 2009 Notice of Appeal and the present Appeal Brief address the final rejections by the Examiner as set forth in his March 4, 2009 Office Action.

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I. REAL PARTY IN INTEREST

The party named in the caption of this Appeal Brief, Pedro M. Buarque de Macedo, of 6100 Highboro Drive, Bethesda, Maryland 20817, the United States of America, is the real party in interest.

II. RELATED APPEALS AND INTERFERENCES

U.S. Patent Application Serial No. 11/607,412 ("the '412 Application") is a divisional patent application claiming priority to the subject application. The '412 Application has been pending before the same Examiner as the subject application. In the '412 Application, a final rejection was issued on September 15, 2008, and the applicant filed a Notice of Appeal on February 17, 2009, and filed his appeal brief on September 17, 2009. Subsequently, the Examiner issued the Examiner's Answer to the appeal brief by the applicant on December 30, 2009, maintaining the final rejection of the pending claims in the '412 Application. In response, the applicant filed a reply brief on February 26, 2010, rebutting the Examiner's Answer and his final rejection of the pending claims in the '412 Application. As of this writing, the appeal of the final rejection of the pending claims of the '412 Application remains pending before the Board of Patent Appeals and Interferences.

III. STATUS OF THE CLAIMS

Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 are currently pending in the subject application. All of these claims stand rejected under a final rejection which issued on March 4, 2009, and are the subject of the present appeal.

Claims 2-4, 6-12, 15-22, 24-26, 28, 32-36, 38-41, 48-50 and 60-62 have been canceled and are not on this Appeal. Claims 6-12, 15-22, 28, 32-36 and 38-41 were withdrawn in the March 18, 2005 Amendment in response to the Examiner's restriction requirement. Subsequently, Appellant canceled without prejudice the above withdrawn claims as well as Claims 2-4, 24-26, 48-50 and 60-62 in the June 26, 2006 Amendment, specifically reserving the right to pursue the claims of comparable scope in future applications.

On December 1, 2006, Appellant filed the '412 Application, as a divisional application, to pursue some of the canceled claims or claims comparable in scope thereto. As of this writing, the appeal of the final rejection of the pending claims in the '412 Application remains pending before the Board of Patent Appeals and Interferences.

Attached hereto as Claims Appendix is a clean copy of Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 involved in this Appeal.[2]

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[2] CLAIMS APPENDIX to this Appeal Brief includes the pending claims under final rejection as last amended by the Amendment Pursuant to 37 C.F.R. § 41.33(a) filed by Appellant on January 17, 2008, before the Examiner subsequently reopened the prosecution and then Appellant reinstated an appeal. The January 17, 2008 Amendment was intended to, *inter alia*, correct a minor informality in Claim 53 which was identified by the Examiner in the August 24, 2007 Office Action. The Examiner's Advisory Action mailed on February 14, 2008 indicated that this amendment would be entered for the purpose of appeal. No further claim amendment has been made since then.

IV. STATUS OF AMENDMENTS

No amendment has been filed subsequent to the March 4, 2009 final rejection.

V. SUMMARY OF CLAIMED SUBJECT MATTER

The claimed subject matter of the present application as set forth in the claims on this Appeal is directed to prestressed, strong foam glass tiles that can be used as building materials in construction. The present invention using prestressing technique applies a substantial amount of prestress compression (*e.g.*, 4,000 pounds per square inch (psi) or greater) to further strengthen very strong foam glass tiles which already have a compression strength unattainable by prior art foam glass (*e.g.*, 10,000 psi or greater).

Such strong foam glass tiles which are capable of having a high compression strength are disclosed in U.S. patent application Serial No. 10/625,071 ("the '071 Application"), which is another commonly owned patent application filed by Appellant on the same day as the present application and which has been incorporated by reference in its entirety into the present application. *See* Application, par. [0026] (as amended by Amendment dated October 19, 2005); *see also* Declaration Under 37 C.F.R. § 1.132 dated May 1, 2007 ("the Declaration of Dr. Macedo," Evidence App. 10), pars. 19, 25 & 26.[3] The '071 Application discloses novel strong foam glass tiles having small pore sizes with, *inter alia*, a compression strength of over 10,000 psi. The pending claims of the '071 Application were allowed by the U.S. Patent Office and the '071

[3] A copy of Declaration of Dr. Macedo is included as Exhibit 10 in EVIDENCE APPENDIX to this Appeal Brief.

Application issued as U.S. Patent No. 7,311,965 B2 on December 25, 2007.[4] A continuation of the '071 Application, U.S. patent application Serial No. 11/728,667 (filed March 27, 2007), is currently pending in the U.S. Patent Office.

The present invention is directed to prestressing such strong foam glass tiles having a compression strength in excess of 10,000 psi prior to prestress compression to attain a prestress compression in excess of 4,000 psi. Among the unexpected results of practicing the claimed invention is that, for example, the traditional building materials such as reinforced or prestressed concrete could be replaced by the prestressed foam glass tiles which are stronger, but lighter, and more durable under various conditions including extreme weather conditions.

In light of the ever-present danger of terrorist attacks, there has always been the need and desire to develop building materials that are capable of withstanding the shock waves and other destructive effects of a bomb explosion or the like. *See* Application, par. [0002].[5] However, the traditional building materials such as reinforced concrete or prestressed concrete have various shortcomings as noted by the present application. *See* Application, par. [0003]. For example, while the prestressed concrete has many advantages over the reinforced counterpart and has been used when stronger materials are desired, the prestressing of concrete requires complex support structure. In addition,

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4 After the '965 Patent issued, Appellant was awarded Inventor of the Year for his work with foam glass materials by the New York Intellectual Property Law Association in May 2008. *See Annual Meeting and Dinner May 21, 2008*, NYIPLA Bulletin, Nov./Dec. 2008, at 17 (http://www.nyipla.org/Bulletin/NovDec2008.pdf).

5 The Application paragraph numbers cited in this Appeal Brief correspond to the paragraph numbers appearing in the subject application as originally filed.

the likely presence of water in the prestressed concrete tends to weaken the prestressed concrete structure under various conditions. *See id.* On the other hand, while the use of conventional foam glass as a construction material has been known, its typical use as a high temperature insulator requires minimization of its density and weight, which does not make it suitable for absorbing the sufficient amount of energy from the shock wave from a bomb explosion, or resisting an earthquake or wind/heat loading. *See* Application, pars. [0004]-[0012]. Accordingly, there is a need and desire for a building material which has the benefit of the added strength of the prestressed concrete while having a less weight and requiring less support structure, i.e., without having the shortcomings of the prestressed concrete. *See id.*, par. [0003].

The prestressed foam glass tiles as claimed in the present application are capable of absorbing a substantial portion of the blast energy from a shock wave of an explosion. *See* Application, par. [0029]. In addition, the prestressed foam glass tiles of the present invention are heat insulating and fire proof and capable of withstanding high temperature, wind loading and other mechanical forces resulting from an explosion. *See* Application, pars. [0022] & [0032]. Accordingly, these prestressed foam glass tiles may be used on interior or exterior surfaces of buildings that are at risk of exposure to explosions or other types of terrorist attacks. *See* Application, pars. [0029] & [0032].

The claimed subject matter as set forth in independent Claims 1, 23, 42 and 54 on this Appeal are briefly summarized as follows:

A. Independent Claim 1

For independent Claim 1, the claimed subject matter is a prestressed foam glass tile which had a compression strength of 10,000 psi or greater prior to being in the prestressed condition, and has been prestressed by 4,000 psi or greater.

Examples 5-7 described in TABLE 1 and paragraph [0052] of the present application disclose the foam glass tile having a compression strength of 10,000 psi or greater prior to being in the prestressed condition. Paragraphs [0023] and [0063]-[0066] of the present application support prestressing such foam glass tiles, using a prestress compression of 4,000 psi or greater.

B. Independent Claim 23

For independent Claim 23, the claimed subject matter is a prestressed assembly for use in buildings or other structures comprising (1) at least one prestressed foam glass tile with a prestress compression of 4,000 psi or greater, which had a compression strength of 10,000 psi or greater prior to being in the prestressed condition; (2) at least two metal beams; and (3) one or more tension members. In the claimed prestressed assembly, the prestressed foam glass tile is placed between the two metal beams and held in compression of at least 4,000 psi by the tension members.

As discussed in connection with the claimed subject matter for independent Claim 1, Examples 5-7 described in TABLE 1 and paragraph [0052] of the present application disclose the foam glass tile having a compression strength of 10,000 psi or greater prior to being in the prestressed condition. Paragraphs [0023] and [0063]-[0066] of the

present application support prestressing such foam glass tiles, using a prestress compression of 4,000 psi or greater.

An exemplary embodiment of the claimed subject matter is illustrated in FIG. 1 of the present application. FIG. 1 shows a prestressed assembly 10 comprising a prestressed foam glass tile 12 placed between two steel beams 26 which are bolted together and held in compression by two tension bolts 18 acting as tension members. *See* Application, pars. [0035] & [0053]. FIG. 2 shows another alternative embodiment for the claimed prestressed assembly 10A, comprising, *inter alia*, multiple foam glass tiles 12A, 12B, 12C held between steel beams 26. *See* Application, par. [0047].

C. Independent Claim 42

For independent Claim 42, the claimed subject matter is a prestressed foam glass tile with a prestress compression of 4,000 psi or greater and an average pore size of 1.0 mm or less, as measured based on the distance between two farthest points of the pore surface. Examples 1-7 described in TABLE 1 and paragraph [0052] of the present application disclose the foam glass tile having an average pore size (or characteristic length) of 1.0 mm or less (incorporating by reference Examples 3-9 of TABLE 3 & par. [0028] of U.S. Patent No. 7,311,965 B2). Paragraphs [0023] and [0063]-[0066] of the present application support prestressing such foam glass tiles, using a prestress compression of 4,000 psi or greater.

D. Independent Claim 54

For independent Claim 54, the claimed subject matter is a prestressed assembly for use in buildings or other structures comprising (1) at least one prestressed foam glass

tile with a prestress compression of 4,000 psi or greater and an average pore size of 1.0 mm or less, as measured based on the distance between two farthest points of the pore surface; (2) at least two metal beams; and (3) one or more tension members. In the claimed prestressed assembly, the prestressed foam glass tile is placed between the two metal beams and held in compression of at least 4,000 psi by the tension members.

As discussed above in connection with the claimed subject matter for independent Claim 42, Examples 1-7 described in TABLE 1 and paragraph [0052] of the present application disclose the foam glass tile having an average pore size (or characteristic length) of 1.0 mm or less (incorporating by reference Examples 3-9 of TABLE 3 & par. [0028] of U.S. Patent No. 7,311,965 B2). Paragraphs [0023] and [0063]-[0066] of the present application support prestressing such foam glass tiles, using a prestress compression of 4,000 psi or greater.

An exemplary embodiment of the claimed subject matter is illustrated in FIG. 1 of the present application. FIG. 1 shows a prestressed assembly 10 comprising a prestressed foam glass tile 12 placed between two steel beams 26 which are bolted together and held in compression by two tension bolts 18 acting as tension members. *See* Application, pars. [0035] & [0053]. FIG. 2 shows another alternative embodiment for the claimed prestressed assembly 10A, comprising, *inter alia*, multiple foam glass tiles 12A, 12B, 12C held between steel beams 26. *See* Application, par. [0047].

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL[6]

A. Rejection of Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 ("The First Rejection")

Whether Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 are unpatentable under 35 U.S.C. § 103(a) over

- U.S. Patent No. 4,324,037 to Grady, II ("Grady," Evidence App. 1)

in view of

- U.S. Patent No. 3,292,316 to Zeinetz ("Zeinetz," Evidence App. 3)

when considering either

- U.S. Patent No. 4,124,365 to Williams et al. ("Williams et al.," Evidence App. 4), or
- U.S. Patent No. 3,056,184 to Blaha ("Blaha," Evidence App. 5),

and further considering any of

- U.S. Patent No. 3,459,565 to Jones et al. ("Jones et al.," Evidence App. 6),
- U.S. Patent No. 3,592,619 to Elmer et al. ("Elmer et al.," Evidence App. 7), and
- U.S. Patent No. 2,758,937 to Ford ("Ford," Evidence App. 8).

See March 4, 2009 Office Action at 2-4.

B. Rejection of Claims 1, 5, 13, 14, 42-47, and 51-53 ("The Second Rejection")

Whether Claims 1, 5, 13, 14, 42-47 and 51-53 are unpatentable under 35 U.S.C. § 103(a) over

- U.S. Patent No. 3,430,397 to Ellis ("Ellis," Evidence App. 2)

in view of

- Zeinetz

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6 A copy of each of the prior art references relied upon by the Examiner as to the grounds of the final rejection in the March 4, 2009 Final Office Action is included in the EVIDENCE APPENDIX to this Appeal Brief.

when considering either

- Williams et al., or
- Blaha,

and further considering any of

- Jones et al.,
- Elmer et al., and
- Ford.

See March 4, 2009 Office Action at 5-7.

The Examiner in the context of this rejection substitutes Ellis for Grady, and utilizes the remaining prior art in the same manner as discussed with respect to the first ground of rejection. Once again, the Examiner recognizes that "Ellis does not present the tile units 12 as made of a foamed glass." March 4, 2009 Office Action, at 5.

C. Rejection of Claims 23, 27, 29-31, 37, 54-59 and 63-66 ("The Third Rejection")

Whether Claims 23, 27, 29-31, 37, 54-59 and 63-66 are unpatentable under 35 U.S.C. § 103(a) over

- Ellis

in view of

- Zeinetz

when considering either

- Williams et al.; or
- Blaha

and further considering any of

- Jones et al.,
- Elmer et al., and
- Ford

as applied to Claims 1, 5, 13, 14, 42-47 and 51-53, and further in view of

- Grady.

See March 4, 2009 Office Action at 7-8.

The Examiner in the context of his last rejection uses all of the above prior art in the same manner as discussed above.

VII. ARGUMENT

A. Summary of Argument

The pending claims at issue on appeal are directed to a novel and non-obvious prestressed foam glass tile (*e.g.*, Claims 1 and 42) or prestressed assemblies comprised of such foam glass tiles (*e.g.*, Claims 23 and 54) using very strong foam glass tiles. The present invention is enabled by using strong "foam glass tiles" taught in the '071 Application which was filed on the same day as the present application, incorporated by reference into the present application, and owned by the same Applicant.

Each of the pending claims requires that the claimed foam glass tiles not only be comprised of "***foam glass***," but also have a "***prestressed compression of 4,000 psi or greater***." (*See* Claims 1, 23, 42, and 54, and their respective dependent claims). (Dependent claims 5, 27, 51, and 63 require an even greater prestressed compression strength). The only cited prior art that the Examiner contends which purportedly teaches prestressing "***foam glass tile***" is Zeinetz (Evid. App. 3), which even the Examiner does not contend teaches prestressing such tiles by 4,000 psi or greater. As discussed in Section VII.B., Appellant disputes that one of ordinary skill in the art reading Zeinetz would understand it to teach prestressing foam glass tiles at all, let alone by the claimed amount.

Independent Claims 1 and 23 (and their respective dependent claims) also require that the claimed foam glass tiles have ***"a compression strength of 10,000 psi or greater prior to being in a prestressed condition."*** Once again, none of the cited prior art teaches a "foam glass tile" which is capable of compression strength of

10,000 psi or greater as claimed. At best, the Examiner cites to Williams et al., which issued in 1978, and Blaha which issued in 1962, as evidence that it would be obvious that one of ordinary skill in the art could make "foam glass tiles" that are strong enough to be prestressed in accordance with the claims. As discussed in Section VII.C., Applicant disputes that either of these references would enable one of ordinary skill in the art to make a foam glass tile with the claimed compression strength, let alone a foam glass tile which is also capable of being prestressed. Appellant also respectfully submits that the Examiner's efforts to combine Williams et al. and/or Blaha with Zeinetz is misplaced and not properly supported by the record.

Independent Claims 42 and 54 (and their respective dependent claims) require, in addition to prestressed foam glass tiles which are compressed 4,000 psi or greater, that the foam glass tiles have "***an average pore size of 1.0 mm or less, wherein said average pore size is measured based on the distance between two farthest points of pore surface.***" (Dependent claims 43-47 and 55-59 require an even smaller average pore size). While the Examiner cites to Jones et al., Elmer et al. and Ford as each disclosing "foam glass components . . . with a pore size of from 0.1 mm to 0.8mm or smaller," even the Examiner does not contend that any of these materials produce a foam glass tile which is strong enough to be prestressed under a prestress compression of 4,000 psi or greater. As discussed in Section VII.D., while the claimed small pore size may be a necessary condition to make a strong enough foam glass tile as taught in the present application, it is not sufficient. Thus, Appellant also respectfully

submits that the Examiner's efforts to combine Jones et al., Elmer et al. and Ford with Zeinetz is again misplaced and not properly supported by the record.

For each of these independent reasons, as discussed herein, Appellant respectfully submits that the Examiner's rejections of the pending claims should be overturned, and each of the pending claims on appeal should be allowed.

B. Each of the First, Second, and Third Rejections of the Pending Claims As Being Unpatentable Over Prior Art Under 35 U.S.C. § 103(a) Should Be Reversed Because Either Individually Or In Combination, the Prior Art Does Not Teach or Suggest Prestressing a Foam Glass Tile By 4,000 psi or Greater

All of the pending claims on this Appeal in the subject application, *i.e.*, Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66, require, *inter alia*, a "***prestressed foam glass tile***" having "***a prestress compression of 4,000 psi or greater***" for the claimed prestressed foam glass tile. Each of the Examiner's First, Second and Third Rejections relies upon Zeinetz to purportedly show prestressing of foam glass tiles.

Appellant respectfully submits, as further explained below, that the Examiner's rejections of Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 should be overturned since:

- None of the cited prior art teaches or suggests a prestressed foam glass tile having any amount of prestress compression, let alone the claimed range of prestress compression. *See infra* Section VII.B.1.
- None of the cited prior art shows any reasonable expectation of success for obtaining the claimed range of prestress compression. *See infra* Section VII.B.2.
- None of the cited prior art enables the claimed range of prestress compression. *See infra* Section VII.B.3.

1. Prior Art Does Not Teach or Suggest the Claimed Range of Prestress Compression

To judge the patentability of a claim against prior art, all claim limitations must be considered. *See* MPEP § 2143.03. In particular, as a prerequisite to a proper obviousness analysis under 35 U.S.C. § 103, each and every claim limitation must be found to exist in the combination of the prior art references. *See Abbott Labs. v. Sandoz, Inc.*, 500 F. Supp. 2d 846, 852 (N.D. Ill. 2007), *aff'd*, 544 F.3d 1341, 1351 (Fed. Cir. 2008) ("Prior to the issuance of the *KSR* opinion, Federal Circuit precedent taught that all the claim limitations of the invention at issue must be found to exist in the prior art references before it could be determined whether there was a teaching, motivation, or suggestion to combine those limitations. . . . The *KSR* opinion . . . did not mention or affect the requirement that each and every claim limitation be found present in the combination of the prior art references before the analysis proceeds."). However, as shown below, none of the prior art references relied upon by the Examiner--Grady, Ellis, Zeinetz, Williams et al., Blaha, Jones et al., Elmer et al., and Ford--teaches or even suggests, either individually or in combination, a prestressed foam glass tile having ***any*** amount of prestress compression, let alone the limitation of "a prestress compression of ***4,000 psi or greater***" recited in the rejected claims. *See* Declaration of Dr. Macedo, pars. 5-14.[7] Based on the foregoing reason alone, each of the Examiner's final rejections should be reversed, and all the pending claims allowed.

[7] Declaration Under 37 C.F.R. § 1.132 ("the Declaration of Dr. Macedo," Evidence App. 10) by Appellant and the inventor, Dr. Pedro M. Buarque de Macedo, was submitted to the Examiner on May 2, 2007, as part of the response to the September 11, 2006 Office Action. As noted

In each of the three rejections advanced by the Examiner, the only reference which he contends teaches prestressing foam glass tiles in any amount is Zeinetz.[8] Specifically, the Examiner states:

> However, Zeinetz teaches utilization of foamed glass tiles or blocks within a tensioned structural arrangement, col. 3, line 73 to col. 4, line 4. Fig. 11 of Zeinetz, for example, shows tension bolts 36, 39 holding foamed glass tiles, col. 4, lines 5-9, in place.

(March 4, 2009 Office Action, at 2). The Examiner further states in response to Appellant's arguments:

> . . . Zeinetz necessarily discloses foamed glass tiles/blocks in a prestressed arrangement with the tension bolts serving to hold the foamed glass blocks of Zeinetz in compression. The application of stretching member 38 tensions the bolts, thus placing compression upon the tiles/blocks of Zeinetz.

(*Id.* at 9).

Zeinetz is directed to a roof structure of the cupola or shell type, as shown in FIGS. 1 and 2 of Zeinetz. In an effort to combine with other references to obtain a foam glass tile under prestress compression, the Examiner contends, without much elaboration, that "Zeinetz necessarily discloses foamed glass tiles/blocks in a prestressed arrangement with the tension bolts serving to hold the foamed glass blocks of Zeinetz in compression." March 4, 2009 Office Action, at 9. ***However, contrary to the***

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above, a copy of the Declaration of Dr. Macedo is included in the EVIDENCE APPENDIX 10 to this Appeal Brief.

[8] While in the First and Third Rejections, the Examiner cites Grady II and in the Second and Third Rejections, the Examiner cites Ellis to show prestressing of other materials, the Examiner recognizes that neither Grady II nor Ellis teach prestressing "foam glass" tiles:

- "Grady II does not present the tiles 82 as made of a foamed glass" (March 4, 2009 Office Action at 2); and
- "Ellis does not present the tile units 12 as made of a foamed glass." (*Id.* at 5).

Examiner's contention, Zeinetz does not teach or even suggest prestressing of a foam glass tile under any amount of prestress compression. *See* Declaration of Dr. Macedo, par. 7.

To support his position that Zeinetz discloses prestressing of a foam glass material, the Examiner points to tension bars 36, 39 in FIG. 11 of Zeinetz and asserts that these tension members hold foam glass tiles, citing Col. 4, lines 5-9 of the Patent. *See* March 4, 2009 Office Action at 2. ***However, contrary to the Examiner's assertion, FIG. 11 of Zeinetz does not teach or suggest the prestressing of a foam glass tile under any amount of prestress compression.*** *See* Declaration of Dr. Macedo, par. 8.

In conjunction with FIG. 5, Zeinetz teaches that the seam 19, 119, 21 and 121 is adapted to fit the abutting lateral edge portions of adjacent roof elements (e.g., a1, a2, b2, c1, c2, and d in FIG. 5). *See* Zeinetz, Col. 3, lines 1-7. FIG. 11 illustrates the section of FIG. 5 along the line B--B and represents "coupling means" for abutting roof elements. *Id.*, Col. 2, lines 4-6 (emphasis added). In fact, Zeinetz explicitly describes the tension bars 36 and 39 in FIG. 11 as "a locking means for use in connection with a U-shaped or tubular seam 19e, 119e, 21e and 121e." *Id.*, Col. 3, line 73 - Col. 4, line 4. In other words, the tension bars 36 and 39 in FIG. 11 are merely coupling or connecting means in conjunction with the U-shaped/tubular seam 19, 119, 21, 121 to keep adjacent roof elements together. Nowhere in Zeinetz is there any teaching or suggestion that the tension bars 36, 39 in FIG. 11 pointed out by the Examiner are the means for

prestressing foam glass tiles, let alone providing prestress compression of 4,000 psi or greater. *See* Declaration of Dr. Macedo, par. 8.

It is also noted that Zeinetz teaches that the rows of interengaging profiles 19, 119, 21, 121 which keep each roof element in wedged engagement with the adjacent elements may render possible the "prestressing of the shell of the cupola." Zeinetz, Col. 3, lines 7-17. As evidenced by the Declaration of Dr. Macedo, it would be clear to a person of ordinary skill in the art that such "prestressing of the shell of the cupola" only refers to providing a structural support to a dome by keeping all the roofing elements together in wedged engagement, hence "self-supporting roof" as the title of Zeinetz states. ***As understood by a person of ordinary skill in the art, this is different from the prestressing applied to foam glass tiles to further strengthen them in accordance with the present invention.*** *See* Declaration of Dr. Macedo, par. 9; *see also* EDWARD G. NAWY, PRESTRESSED CONCRETE: A FUNDAMENTAL APPROACH 8-10 (1989)[9] ("the Nawy Reference," Evidence App. 9) (defining prestressing as used in the present application). Furthermore, such person would also understand that the wedged engagement with neighboring elements as shown in Zeinetz cannot possibly provide a prestress compression of 4,000 psi or greater. *See* Declaration of Dr. Macedo, par. 9. Therefore, Zeinetz does not teach, or even suggest at all, the prestressing of a foam glass tile under a prestress compression of 4,000 psi or greater as required by the claims on this Appeal.

[9] A copy of the relevant portions of the Nawy Reference is included in the EVIDENCE APPENDIX 9 to this Appeal Brief.

Moreover, Zeinetz teaches a litany of roofing materials that could be used, including glass, wood, synthetic plastic, concrete, porous concrete, foamed plastic, foamed glass, cardboard, sheet metal, wool, cork and fiber board. *See* Zeinetz, Col. 4, lines 5-20. These materials are used in a multi-layer structure where each layer is for a different purpose such as a "moisture-insulating layer" consisting of a "heat insulating layer," a "load sustaining layer" and a "sound absorbing layer." *See* Zeinetz, Col. 4, lines 8-15. The kind of layer that "foamed glass" may be used for is not taught. However, the load sustaining layer, which is the layer that would potentially be under compression, "is made of concrete, for example." *Id.*, Col. 4, line 14. ***There is no teaching or suggestion that the load sustaining layer could be made of prestressed foam glass tiles, let alone foam glass tiles having a prestress compression of 4,000 psi or greater.*** *See* Declaration of Dr. Macedo, par. 10.

Based on the foregoing reason alone, the Examiner has not established a *prima facie* case of obviousness of Claims 1, 5, 13, 14, 23, 27, 29-31, 37 and 42-47, 51-59 and 63-66 over the above-cited prior art under 35 U.S.C. § 103(a). Accordingly, Appellant is entitled to reversal of all of the Examiner's final rejections and allowance of all of the pending claims on this Appeal over the cited prior art. *See In re Oetiker*, 977 F.2d 1443, 1445 (Fed. Cir. 1992) ("If examination at the initial stage does not produce a prima facie case of unpatentability, then without more the applicant is entitled to grant of the patent.").

2. Prior Art Shows No Reasonable Expectation of Success for Obtaining the Claimed Range of Prestress Compression

Another reason why the Examiner fails to establish a *prima facie* case of obviousness with respect to the rejected claims is that none of the prior art references relied upon by the Examiner, either individually or in combination, shows that there would be a reasonable expectation of success for a person of ordinary skill in the art to achieve the claimed invention based on the alleged prior art combinations. Evidence showing that there was no reasonable expectation of success may support a conclusion of non-obviousness. *See* MPEP § 2143.02; *see also In re Vaeck*, 947 F.2d 488, 493 (Fed. Cir. 1991); *Amgen, Inc. v. Chugai Pharm. Co.*, 927 F.2d 1200, 1207-08 (Fed. Cir. 1991); *In re Rinehart*, 531 F.2d 1048, 1053-54 (C.C.P.A. 1976).

In support of the final rejection, the Examiner further contends that "[a]pplying a pre-compressive force of from 1,000 to 5,000 psi to the resulting assembled foam glass units, thus affording as much recovery from the effects of a greater degree of overload, would have constituted a further obvious expedient to one having ordinary skill in the art at the time the invention was made." March 4, 2009 Office Action at 3-4. However, the Examiner's contention must fail in view of the evidence showing that there was no reasonable expectation of success by a person of ordinary skill in the art for obtaining a prestressed foam glass tile having a prestress compression of 4,000 psi or greater based on the prior art combinations relied upon by the Examiner. As evidenced by Declaration of Dr. Macedo and addressed in the previous section of this Appeal Brief, neither Zeinetz nor any other prior art reference relied upon by the Examiner discloses or even suggests

the prestressing of a foam glass tile under ***any*** amount of a prestress compression, let alone a prestress compression within the claimed range of 4,000 psi or greater. Furthermore, the Examiner failed to show any foam glass tile materials which could be used to be prestressed under 4,000 psi or greater. In the absence of any teaching of prestressing of a foam glass tile, a person of ordinary skill in the art would not be reasonably expected to succeed in obtaining the subject matter of the rejected claims, including a prestressed foam glass tile under a prestress compression of 4,000 psi or greater, merely on the basis of the prior art relied upon by the Examiner.

To support the final rejections, the Examiner also refers to his prior Response to Arguments set forth in the August 24, 2007 Office Action wherein the Examiner contended that "[f]act that claimed combination of elements was 'obvious to try' might show that such combination was obvious under 35 U.S.C. 103," citing *KSR Int'l Co. v. Teleflex Inc.*, 82 U.S.P.Q.2d (BNA) 1385 (U.S. 2007). *See* March 4, 2009 Office Action at 12; August 24, 2007 Office Action at 12. To reject a claim based on such "obvious to try" rationale, the Examiner must articulate the following findings:

> (1) a finding that at the time of the invention, there had been a recognized problem or need in the art, which may include a design need or market pressure to solve a problem;
>
> (2) a finding that there had been a finite number of identified, predictable potential solutions to the recognized need or problem;
>
> (3) a finding that one of ordinary skill in the art could have pursued the known potential solutions with a ***reasonable expectation of success***; and
>
> (4) whatever additional findings based on the Graham factual inquiries may be necessary, in view of the facts of the

> case under consideration, to explain a conclusion of obviousness.

MPEP 2143.E. (emphasis added); *see also KSR*, 82 U.S.P.Q.2d at 1397 (holding that the fact that a combination was obvious to try might show that it was obvious under 35 U.S.C. § 103 ***if***, *inter alia*, a person of ordinary skill pursuing the known options ***within his or her technical grasp*** is led to the ***anticipated success***).

However, the Examiner of the subject application fails to explain or justify such "obvious to try" rationale in the March 3, 2009 Office Action or in any other prior Office Actions. Other than merely reciting the general guideline for supporting the "obvious to try" rationale set forth by the Supreme Court in *KSR*, the Examiner never articulated any of the necessary findings to support such rationale. Even assuming *arguendo* that the Examiner somehow articulated his findings that at the time of the invention, there had been a recognized problem or need in the art and that there had been a finite number of identified, predictable potential solutions to such problem or need, for which Appellant contends the Examiner never established any sufficient support, the Examiner failed to articulate a finding as to ***how*** a person of ordinary skill in the art could have pursued, with a reasonable expectation of success, the allegedly known potential solutions disclosed in the prior art to obtain the claimed foam glass tile having a prestress compression of 4,000 psi or greater. The Examiner could not, since, as Appellant showed in the previous paragraphs, no reasonable expectation of success can be found from Zeinetz or any other prior art, as they do not teach or suggest any amount of prestress compression for the claimed foam glass tile. The Examiner has also failed to show any foam glass tile materials which could be used to be prestressed under 4,000 psi

or greater. Since the finding of a reasonable expectation of success cannot be made, the Examiner's "obvious to try" rationale cannot be used to support his conclusion that the claims under final rejection would have been obvious to one of ordinary skill in the art. *See KSR* Guidelines, 72 Fed. Reg. at 57,532; MPEP § 2143.E.

Based on at least the foregoing reasons, the Examiner failed to establish a *prima facie* case of obviousness of Claims 1, 5, 13, 14, 23, 27, 29-31, 37 and 42-47, 51-59 and 63-66 over the above-cited prior art under 35 U.S.C. § 103(a). Accordingly, Appellant is entitled to reversal of all of the Examiner's final rejections and allowance of all of the pending claims on this Appeal over the cited prior art. *See In re Oetiker*, 977 F.2d at 1445.

3. Prior Art Also Does Not Enable the Claimed Range of Prestress Compression

Furthermore, to render an invention unpatentable for obviousness, the prior art must ***enable*** one of ordinary skill in the art to make and use the invention. *See KSR*, 82 U.S.P.Q.2d at 1396 ("[I]f a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious ***unless its actual application is beyond his or her skill***." (emphasis added)); *In re Kumar*, 418 F.3d 1361, 1368 (Fed. Cir. 2005) ("[W]hen a *prima facie* case of obviousness is deemed made based on similarity to a known composition or device, rebuttal may take the form of evidence that the prior art does not enable the claimed subject matter."); *id.* at 1369 ("To render a later invention unpatentable for obviousness, the prior art must enable a person of ordinary skill in the field to make and use the later invention."); *see also In re Payne*, 606 F.2d 303, 314-15

(C.C.P.A. 1979) ("[T]he presumption of obviousness based on close structural similarity is overcome where the prior art does not disclose or render obvious a method for making the claimed compound.").

However, neither Zeinetz nor any other prior art relied upon by the Examiner provides any disclosure or cite any supporting reference that would ***enable*** one of ordinary skill in the art to prestress a foam glass tile under any amount of prestress compression, let alone the claimed range of 4,000 psi or greater. Accordingly, even if a *prima facie* case of obviousness was deemed made based on the prior art combinations relied upon by the Examiner, which Appellant contends it cannot, such *prima facie* case is rebutted by the evidence showing that none of the prior art references relied upon by the Examiner teaches or suggests the claimed range of prestress compression for a prestressed foam glass tile. *See* Declaration of Dr. Macedo, pars. 5-14.

Accordingly, based on the foregoing reason alone, the final rejections of Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 by the Examiner are in error and should be reversed.

C. Each of the First, Second and Third Rejections of the Claims Having the Compression Strength Limitation As Being Unpatentable Over Prior Art Under 35 U.S.C. § 103(a) Should Be Reversed Because Either Individually Or In Combination, the Prior Art Does Not Teach or Suggest a Foam Glass Tile Having a Compression Strength of 10,000 psi or Greater Prior To Prestress Compression

In addition to the prestress compression limitation discussed in Section VII.B. above, each of Claims 1, 5, 13, 14, 23, 27, 29-31 and 37 on this Appeal also requires, *inter alia*, "***a compression strength of 10,000 psi or greater prior to being in a***

prestressed condition" for the claimed prestressed foam glass tile. In each of the First, Second and Third Rejections, the Examiner cites to Williams et al., which issued in 1978, and Blaha '184 Patent which issued in 1962, as evidence that it would be obvious that one of ordinary skill in the art could make "foam glass tiles" that are strong enough to be prestressed in accordance with the claims.

Appellant respectfully submits, as further explained below, that the Examiner's rejections of Claims 1, 5, 13, 14, 23, 27, 29-31 and 37 should be overturned since:

- None of the cited prior art teaches or suggests the claimed range of compression strength. *See infra* Section VII.C.1.
- There is no apparent reason to combine the cited prior art to obtain a foam glass tile that is strong enough for the claimed range of prestress compression. *See infra* Section VII.C.2.
- Rather, the cited prior art disclosing compression strength below the claimed range teaches away from the claimed range of prestress compression. *See infra* Section VII.C.3.
- None of the cited prior art enables the claimed range of compression strength. *See infra* Section VII.C.4.

1. Prior Art Also Does Not Teach or Suggest the Claimed Range of Compression Strength

In each of the three rejections advanced by the Examiner, the only prior art references he relies on for disclosing the necessary compression strength are Williams et al. and Blaha. Specifically, the Examiner states:

> And, each of Williams et al., as at col. 1, lines 35-43, and Blaha, as at col. 3, lines 24-35, teach utilization of foamed glass tiles or blocks possessing a compressive strength in excess of 1200 psi with Williams et al. teaching a compressive strength on the order of 5,000 to 8,000 psi with each of Williams et al. and Blaha disclosing use of the foam glass as a structural member sufficiently strong for structural

> purposes within the building industry, col. 1, lines 19-22 of Williams et al. and col. 1, lines 10-28 of Blaha.

(March 4, 2009 Office Action at 3). However, the Examiner's position is again erroneous, as ***neither Williams et al., nor Blaha teaches or suggests a foam glass tile having a compression strength within the claimed range of 10,000 psi or greater.*** *See* Declaration of Dr. Macedo, pars. 15-18 & 21-23.

Significantly, there is no dispute that neither Williams et al, nor Blaha, nor any other prior art relied upon by the Examiner discloses the claimed range of compression strength. Rather, as the basis of his obviousness conclusion, the Examiner merely points to the portions of Williams et al. and Blaha disclosing the ranges of compression strength that do not overlap with, nor do they come close to, the claimed range of 10,000 psi or greater as required by the rejected claims. *See* March 4, 2009 Office Action at 3.

More specifically, the Examiner points to the following portion of Williams et al.: "Such a material should be readily available, easily formed in lengths up to 100 feet, be able to withstand a stress of ***5,000-8,000 psi*** . . ." Williams et al., Col. 1, lines 36-38 (emphasis added). Even assuming *arguendo* that Williams et al. teaches how such compression strength can be achieved, which Appellant contends it cannot, *see infra* Section VII.C.4., this disclosed range still falls short of and does not overlap at all with the claimed range of compression strength of a foam glass tile starting from 10,000 psi and higher as required by the rejected claims. This difference in compression strength is substantial. *See* Declaration of Dr. Macedo, par. 16. Furthermore, as further explained below in Section VII.C.2., Williams et al. is directed to an elongate hollow cylindrical structure, *see* Williams et al., Col. 1, lines 14-25 and FIG. 3, and it does not disclose any

foam glass ***tile*** having 5,000-8,000 psi, let alone the claimed range of 10,000 psi or greater. Accordingly, the Examiner's reliance on Williams et al. to support his obviousness conclusion is misplaced.

The Examiner also points to a portion in Blaha disclosing a slab of cellular, agglomerated material having a compression strength "in excess of 1200 pounds per square inch." Blaha, Col. 3, lines 26-28. The compression strength of 1,200 psi as disclosed by Blaha falls far short of 10,000 psi, the lower end of the claimed range of compression strength required by the rejected claims. To overcome this apparent deficiency, the Examiner further relies on a vague statement of objective taken from a different portion of Blaha that the cellular material is to be "sufficiently strong to be used for structural purposes." Blaha '184 Patent, Col. 1, lines 27-28; *see also* March 4, 2009 Office Action at 3. However, such open-ended statement alone, without any adequate enabling disclosure, cannot enable, or provide any apparent reason to motivate, a person of ordinary skill in the art to achieve, with a reasonable expectation of success, the dramatic increase in compression strength of a foam glass tile from a mere 1,200 psi as disclosed by Blaha to over 10,000 psi required by the rejected claims. *See* Declaration of Dr. Macedo, par. 18. Rather, such statement would ***teach away*** the skilled person from reaching beyond 1,200 psi to achieve a compression strength within the claimed range of 10,000 psi or greater.

Moreover, this statement does not teach that the resulting material can or should be prestressed. If anything, it teaches that prestressing would be unnecessary. Simply put, Blaha does not teach or suggest at all a foam glass tile having a compression

strength within the claimed range of 10,000 psi or greater, let alone a ***prestressed*** foam glass tile with the claimed compression strength ***and*** prestress compression. Accordingly, the Examiner's reliance on Blaha to support his obviousness conclusion is likewise misplaced.

As a prerequisite to a proper obviousness analysis under 35 U.S.C. § 103, each and every claim limitation must be found to exist in the combination of the prior art references. *See Abbott Labs. v. Sandoz, Inc.*, 500 F. Supp. 2d at 852. However, as shown above, neither Williams et al. nor Blaha teaches or suggests "a compression strength of 10,000 psi or greater prior to being in a prestressed condition" for the claimed prestressed foam glass tile. Based on the foregoing reason alone, the Examiner failed to establish a *prima facie* case of obviousness of Claims 1, 5, 13, 14, 23, 27, 29-31 and 37 over the prior art under 35 U.S.C. § 103(a), and as such, Appellant is entitled to reversal of the Examiner's final rejections and allowance of those claims. *See In re Oetiker*, 977 F.2d at 1445.

2. There Is No Apparent Reason To Combine the Teachings of the Cited Prior Art To Obtain the Claimed Ranges of Compression Strength and Prestress Compression

Further, there is no apparent reason to combine the teaching of Williams et al. and/or Blaha with that of Zeinetz to obtain the claimed prestressed foam glass tiles, since neither Williams et al. nor Blaha discloses sufficiently strong foam glass materials having a high enough compression strength for a prestress compression of 4,000 psi or greater.

Specifically, Williams et al. discloses a continuous process for the manufacture of cellular ceramic products in the form of elongate hollow cylindrical members. *See* Williams et al., Col. 1, lines 14-19. However, Williams et al. does not disclose "foam glass ***tiles***," let alone "***prestressed*** foam glass ***tiles***" as required by the present claims. Indeed, the following portion of Williams et al. cited by the Examiner in support of his position, *see* March 4, 2009 Office Action at 3, is the evidence: "***In such form***, the foamed glass product can be used as a structural member in a number of industries including the housing industry as a bearing member . . . ." Williams et al., Col. 1, lines 19-22 (emphasis added). However, "such form" in the cited portion of Williams et al. refers to a "foamed glass" produced "in the form of elongate members, more particularly in the form of ***hollow elongate cylinders***" as recited in the sentence in Williams et al. just before the cited portion, ***not as tiles***. Hence, it is clear that Williams et al. is directed to an elongate structure of foam glass rather than foam glass tiles as in the present invention.

In fact, the description of the preferred embodiment of Williams et al. is directed to production of foam glass in the form of ***hollow elongate cylinders*** so that it can be used as conduit such as sewer pipe, telephone pole, or power line. *See* Williams et al., Col. 1, lines 14-25 & FIG. 3. However, a person of ordinary skill in the art would understand that, unlike in the case of foam glass tiles, prestressing of these foam glass hollow elongate cylinders (which are to be used as conduit, telephone poles, etc.) would not be desirable, nor is it technically feasible or economical. Accordingly, a person of ordinary skill in the art would ***not*** find any apparent reason or motivation to apply

prestressing to a foam glass product described in Williams et al., but would rather be taught away from doing so. *See* Declaration of Dr. Macedo, par. 17. This is one more reason why the Examiner's reliance on Williams et al. is misplaced. Moreover, there is no reason why anyone skilled in the art would turn to the teachings in Williams et al. on how to make foam glass elongated cylinders to allegedly apply "prestressing" when considering the roofing materials disclosed in Zeinetz relied upon by the Examiner.

Likewise, a person of ordinary skill in the art would not find any apparent reason or motivation to apply prestressing to a foam glass product described in Blaha since it does not disclose or suggest foam glass materials that are strong enough for subsequent prestress compression of 4,000 psi or greater. *Cf.* Declaration of Dr. Macedo, par. 18.

In addition, Zeinetz teaches the use of foamed glass only within the context of a "moldable material." *See* Zeinitz, Col. 4, lines 5-8. However, neither Williams et al. nor Blaha teaches a moldable material. Rather, those references are primarily associated with extruded materials. Thus, one of ordinary skill in the art would not look to Williams et al. or Blaha for a suitable "moldable material" for use with the structure disclosed in Zeinitz. There is also no teaching or suggestion in either Williams et al. or Blaha regarding how a "moldable material" foam glass tile can be formed which can be used in a copola-like structure as provided in Zeinetz which could be strong enough to be prestressed to 4,000 psi or greater. Nor is there any indication or suggestion that if the foam glass products of Williams et al. or Blaha are made by moldable materials, instead of extruded materials, they could achieve the claimed compression strength of

10,000 psi or greater and are suitable for a prestress compression of 4,000 psi or greater. *Cf*. Declaration of Dr. Macedo, pars. 17 and 22.

The Examiner never explicitly articulated any rationale for combining Williams et al. or Blaha with Zeinetz, even though the Supreme Court in *KSR* noted that the analysis supporting an obviousness rejection should be made explicit. *See* MPEP § 2143. In fact, as discussed above, there exists no apparent reason why a person of ordinary skill in the art would combine the teaching of Williams et al. and/or Blaha with that of Zeinetz to obtain the claimed prestressed foam glass tiles. Based on at least the foregoing reason, the Examiner's reliance on Williams et al. and Blaha to establish a *prima facie* case of obviousness with respect to Claims 1, 5, 13, 14, 23, 27, 29-31 and 37 is misplaced. Hence, the Examiner's final rejections of those claims are in error and should be reversed.

3. Prior Art Disclosing Compression Strength Below the Claimed Range Teaches Away from the Claimed Range of Prestress Compression

To support obviousness rejections based on prior art combination, the Examiner must articulate, *inter alia*, "a finding that one of ordinary skill in the art would have recognized that the results of the combination were ***predictable***." *KSR* Guidelines, 72 Fed. Reg. at 57,529 (emphasis added); MPEP § 2143 (A); *see also KSR*, 82 U.S.P.Q.2d at 1396 ("[A] court must ask whether the improvement is more than the ***predictable*** use of prior art elements according to their established functions." (emphasis added)). However, no such finding was made by the Examiner in the March 4, 2009 Office Action, despite his reliance on extensive combinations of no less than seven references. In fact,

as shown below, the range of compression strength of foam glass product disclosed by Williams et al. or Blaha relied upon by the Examiner would ***teach away*** a person of ordinary skill in the art from prestressing the foam glass product under a prestress compression of 4,000 psi or greater, a limitation in all of the claims in this Appeal. Hence, no person of ordinary skill in the art could have recognized that the results of the combination were predictable.

As evidenced by the Declaration of Dr. Macedo, it is well known to those skilled in the art of prestresssing that by prestressing a product, the resulting compression strength of the prestressed product will decrease by the prestress amount while the resulting tension strength will increase by the same amount. It is also well understood by those skilled in the art that it is desirable to achieve the optimum amount of prestress level by making the tension strength comparable to the compression strength as the result of prestressing. In other words, the optimum prestress level is one half of the difference between the compression strength and the tension strength under non-prestressed condition. *See* Declaration of Dr. Macedo, par. 20; *see also generally* EDWARD G. NAWY, PRESTRESSED CONCRETE: A FUNDAMENTAL APPROACH 8-13 (1989) (Evidence App. 9). Based on these principles, the optimum prestress level for the foam glass tiles described in TABLE 1 of the present application is calculated to be approximately 44% of the compression strength of the foam glass tile prior to being in the prestressed condition. For example, for a foam glass tile having a compression strength of 10,000 psi prior to being in a prestressed condition, the corresponding optimum prestress compression is approximately 4,400 psi; for the one having a compressional strength of 12,500 psi prior

to being in a prestressed condition, the corresponding optimum prestress compression is approximately 5,500 psi, etc. *See* Declaration of Dr. Macedo, par. 20.

There is no dispute that none of the compression strength ranges disclosed by Williams et al. and Blaha relied upon by the Examiner reaches anywhere near 10,000 psi. At best, the maximum compression strength disclosed by the prior art relied upon by the Examiner is 8,000 psi, which is casually mentioned by Williams et al. without any enabling disclosure, for an elongated tube, not a foam glass tile.[10] Based on the principles discussed above, for a foam glass tile having the maximum disclosed compression strength of 8,000 psi, a person of ordinary skill in the art would desire to achieve the optimum prestress compression of about 44% of 8,000 psi, or about 3,500 psi, which is less than the claimed range of 4,000 psi or greater. *See* Declaration of Dr. Macedo, par. 21.

Accordingly, even if Williams et al. is deemed to be providing an enabling disclosure for a person of ordinary skill in the art to achieve a foam glass tile having a compression strength of up to 8,000 psi, which Appellant contends that it does not for the reasons discussed in the next section, such person still would be ***taught away*** from applying a prestress compression of 4,000 psi or greater to this foam glass tile since that would deviate from the optimum prestress compression level as understood by those skilled in the art. Such person would instead apply a prestress compression of at most 3,500 psi or less, corresponding to the optimum prestress compression for the ranges of

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[10] This difference in structure leads to different geometries which affect the relative strength of the resulting materials. *See* Declaration of Dr. Macedo, pars. 17 & 22.

foam glass compression strength disclosed by the prior art relied upon by the Examiner. *See* Declaration of Dr. Macedo, par. 21. The fact that the prior art relied upon by the Examiner provides no apparent reason for the alleged prior art combinations, but rather teaches away from them further supports Appellant's position that the elements of the claimed invention set forth in the claims work together in an ***unexpected and fruitful manner*** and are therefore not obvious over the prior art. *See KSR*, 82 U.S.P.Q.2d at 1395-96.

There is no apparent reason to combine the prior art because the prior art relied upon by the Examiner teaches away from the combination to obtain the claimed invention. "[W]hen the prior art teaches away from combining certain known elements, discovery of a successful means of combining them is more likely to be non-obvious. . . . The fact that the elements worked together in an unexpected and fruitful manner supported the conclusion that [the claimed invention]was not obvious to those skilled in the art." *KSR Int'l Co. Teleflex Inc.*, 82 U.S.P.Q.2d (BNA) 1385, 1395 (U.S. 2007). Even when there is a presumption of obviousness based on a claimed invention that falls within a range disclosed by the prior art, such presumption can be rebutted if the prior art teaches away from the claimed invention, or if there are new and unexpected results relative to the prior art. *See Iron Grip Barbell Co. v. USA Sports, Inc.*, 392 F.3d 1317, 1322 (Fed. Cir. 2004); *see also* MPEP § 2144.05 (III).

Based on at least the foregoing reason, the Examiner failed to establish a *prima facie* case of obviousness with respect to Claims 1, 5, 13, 14, 23, 27, 29-31 and 37. Even if a *prima facie* case of obviousness was deemed made based on the ranges of foam glass

compression strength disclosed by Williams et al. or Blaha, which Appellant contends it cannot, such *prima facie* case is rebutted by the evidence showing that the prior art ranges of compression strength would teach away those skilled in the art from applying a prestress compression of 4,000 psi or greater to a foam glass tile to achieve the claimed invention. Hence, the Examiner's final rejections of Claims 1, 5, 13, 14, 23, 27, 29-31 and 37 over prior art are in error and should be reversed.

4. Prior Art Also Does Not Enable the Claimed Range of Compression Strength

To render an invention unpatentable for obviousness, the prior art must ***enable*** one of ordinary skill in the art to make and use the invention. *See KSR*, 82 U.S.P.Q.2d at 1396 ("[I]f a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious ***unless its actual application is beyond his or her skill***." (emphasis added)); *In re Kumar*, 418 F.3d 1361, 1368 (Fed. Cir. 2005) ("[W]hen a *prima facie* case of obviousness is deemed made based on similarity to a known composition or device, rebuttal may take the form of evidence that the prior art does not enable the claimed subject matter."); *id.* at 1369 ("To render a later invention unpatentable for obviousness, the prior art must enable a person of ordinary skill in the field to make and use the later invention."); *see also In re Payne*, 606 F.2d 303, 314-15 (C.C.P.A. 1979) ("[T]he presumption of obviousness based on close structural similarity is overcome where the prior art does not disclose or render obvious a method for making the claimed compound."). However, as explained below, neither Williams et al. nor Blaha enables the claimed range of compression strength set forth in the rejected claims.

Williams et al. does not provide any disclosure or cite to any supporting reference that would ***enable*** a person of ordinary skill in the art to achieve a foam glass tile having a compression strength of 10,000 psi or greater as required by the rejected claims. In fact, Williams et al. does not even provide an enabling disclosure for making the elongated tube having a length of up to 100 feet that can possess a compression strength of up to 8,000 psi, which it casually mentions. *See* Williams et al., Col. 1, lines 14-25 and 36-38. As evidenced by the Declaration of Dr. Macedo, such feat would be considered impossible even with today's foam glass technology, let alone in 1978, the issue date of Williams et al.. *See* Declaration of Dr. Macedo, par. 22.

Such claim by Williams et al. would appear inconsistent with its later description of elongate foamed ceramic products made under the process it teaches. *See* Declaration of Dr. Macedo, par. 23. The elongate foamed ceramic product described by Williams et al. has a cellular structure of closed, elongate bubbles with a diameter ranging from 0.01 mm to 1 cm and a length ranging from 2 mm to 5 cm. *See* Williams '365 Patent, Col. 2, lines 19-33. As evidenced by the Declaration of Dr. Macedo, while a small pore size by itself may not be a sufficient condition for a strong foam glass product, it is a necessary condition and a foam glass product having largest bubbles reaching 1 cm and 5 cm in diameter and length, respectively, can never achieve a compression strength as high as 8,000 psi, let alone the claimed compression strength of 10,000 psi or greater, which is sufficiently strong for the purpose of prestress compression within the claimed range. *See* Declaration of Dr. Macedo, par. 23. It is also noted that none of the examples described by Williams et al. has an average pore size less than 1.0 mm. *See, e.g.,*

Williams et al., Col. 6, lines 62-63 and Col. 8, lines 5-6. While none of the examples in Williams et al. provides any compression strength data, a person of ordinary skill in the art would understand that in view of the bubble sizes reported by Williams et al., none of the examples described in Williams et al. can achieve a compression strength within the claimed range of 10,000 psi or greater. *See* Declaration of Dr. Macedo, par. 23. In fact, by teaching a foamed ceramic product having large bubbles, Williams et al. teaches away from making a strong foam glass product suitable for the range of prestress compression required by the present invention.

Despite the dubiousness of such feat of achieving a compression strength of up to 8,000 psi, if it would have been possible at all, Williams et al. is silent on how to go about achieving it. Nowhere in the description of six examples by Williams et al. is there any indication of a reasonable expectation of success of such feat. *See* Declaration of Dr. Macedo, par. 22. When Williams et al. does not enable those skilled in the art to reproduce what the Examiner claims it discloses, namely a foam glass product having a compression strength of 8,000 psi, certainly it would not enable such person to make a foam glass tile having an even greater compression strength of 10,000 psi or greater.

Likewise, despite its claim of a slab of cellular material having a compression strength "in excess of" 1,200 psi, nowhere in Blaha is there any disclosure that would enable a person of ordinary skill in the art to produce a foam glass tile having a compression strength of even 2,000 psi or 3,000 psi, let alone 10,000 psi or greater as required by the rejected claims. In fact, the density of the strongest cellular material disclosed in Blaha, 42 pounds per cubic feet (PCF), is still far too low to achieve the

claimed range of compression strength required by the present invention. *Compare* Blaha '184 Patent, Col. 3, lines 24-28 (disclosing the maximum density of 42 PCF), *with* Application, TABLE 1, Examples 5-7 (disclosing the density of 62 PCF or greater). By teaching a low-density cellular material, Blaha in fact teaches away from making a strong foam glass product suitable for the range of prestress compression required by the present invention.

In summary, even if a *prima facie* case of obviousness was deemed made with respect to Claims 1, 5, 13, 14, 23, 27, 29-31 and 37 based on, *inter alia*, the ranges of foam glass compression strength allegedly disclosed by Williams et al. or Blaha, which Appellant contends it cannot, such *prima facie* case is rebutted by the evidence that neither Williams et al. nor Blaha enables a person of ordinary skill in the art to produce a foam glass tile having a compression strength within the claimed range of 10,000 psi or greater as required by the rejected claims. Based on at least the foregoing reasons, the Examiner's final rejections of Claims 1, 5, 13, 14, 23, 27, 29-31 and 37 over prior art are in error and should be reversed.

D. Each of the First, Second and Third Rejections of the Claims Having the Average Pore Size Limitation As Being Unpatentable Over Prior Art Under 35 U.S.C. § 103(a) Should Be Reversed Because Either Individually Or In Combination, the Prior Art Does Not Teach or Suggest a Foam Glass Tile Having an Average Pore Size of 1.0 mm or Less That Is Strong Enough For a Prestress Compression of 4,000 psi or Greater

In addition to the prestress compression limitation discussed in Section VII.B. above, each of Claims 42-47, 51-59 and 63-66 also requires, *inter alia*, "***an average***

pore size of 1.0 mm or less, wherein said average pore size is measured based on the distance between two farthest points of pore surface, " for the claimed prestressed foam glass tile. In each of the First, Second and Third Rejections, the Examiner cites to Jones et al., Elmer et al. and Ford as each disclosing "manufacture of foam glass components . . . with a pore size of less than 1mm including a pore size of from 0.1mm to 0.8mm or smaller." (March 4, 2009 Office Action, at 3).

Appellant respectfully submits, as further explained below, that the Examiner's rejections of Claims 42-47, 51-59 and 63-66 should be overturned since:

- Neither Jones et al., nor Elmer et al., nor Ford discloses foam glass materials with an average pore size of 1.0 mm or less that are strong enough to be prestressed under the claimed range of 4,000 psi or greater. *See infra* Section VII.D.1.
- Hence, there is no apparent reason to combine Jones et al., Elmer et al., and/or Ford with Zeinetz to obtain the claimed ranges of prestress compression and average pore size. *See infra* Section VII.D.2.

1. None of the Prior Art Discloses Foam Glass Materials With an Average Pore Size of 1.0 mm or Less That Are Strong Enough For a Prestress Compression of 4,000 psi or Greater

While the Examiner cites to Jones et al., Elmer et al. and Ford as each disclosing as each disclosing "manufacture of foam glass components . . . with a pore size of less than 1mm including a pore size of from 0.1mm to 0.8mm or smaller," he does not contend that any of these materials can produce a foam glass tile which is strong enough to be prestressed under a prestress compression of 4,000 psi or greater. (March 4, 2009 Office Action, at 3). At best, Jones et al., Elmer et al. and Ford teach that small pores can exist in foam glass materials. However, unlike the claimed invention, neither Jones et al., nor Elmer et al., nor Ford teaches or even suggests that the disclosed pore sizes

lead to a foam glass tile having a sufficiently high compression strength for the purpose of prestress compression of 4,000 psi or greater, or how to make such tiles. *See* Declaration of Dr. Macedo, pars. 24-27. In fact, ***none of the prior art references relied upon by the Examiner, either individually or in combination, teaches or even suggests that foam glass tiles made with small pore sizes in an appropriate manner can also have the prestress strengths claimed by the rejected claims.***

While the claimed small pore size may be a necessary condition to make a strong enough foam glass tile as taught in the present application, it is not a sufficient condition. Even if its average pore size is small, the foam glass material may still have a low compression strength if the pores are dense and highly interconnected. *See* Declaration of Dr. Macedo, par. 25. In fact, Jones et al. is directed to a low-density foamable granule product having, for example, 18% open cells indicating a high degree of interconnectedness and a small compression strength of 129.6 psi. *See* Jones et al., Col. 8, lines 72-75. Elmer et al. also focuses on "interconnecting pores" as the defining characteristics of its high-silica glass foam. Elmer et al., Col. 2, line 7. Likewise, Ford is directed to a cellulated glass product having the specific gravity of 0.14 to 0.18, Ford, Col. 3, lines 22-24, which corresponds to a low density of 9 to 12 PCF. Hence, despite having small pore sizes, none of the foam glass materials described in Jones et al., Elmer et al. and Ford is strong enough for the purpose of prestress compression of 4,000 psi or greater. *See* Declaration of Dr. Macedo, par. 25.

2. There Is No Apparent Reason to Combine the Prior Art to Obtain the Claimed Ranges of Prestress Compression and Average Pore Size

Since the foam glass materials described in Jones et al, Elmer et al., and Ford are not strong enough for the purpose of prestress compression of 4,000 psi or greater, those references do not provide any apparent reason or motivation for those skilled in the art to combine their teachings with that of Zeinetz or any other prior art to apply a prestress compression of 4,000 psi or greater to a foam glass tile.

The Supreme Court in *KSR Int'l Co. v. Teleflex Inc.*, 82 U.S.P.Q.2d (BNA) 1385 (U.S. 2007) noted that "it can be important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in the way the claimed new invention does." *Id.* at 1396. While warning against applying as rigid and mandatory formulas, the Supreme Court found that this is a "helpful insight." *Id.* The Court in *KSR* further held that an explicit analysis for determining whether there is an apparent reason for prior art combinations should be made:

> Often, it will be necessary for a court to look to interrelated teachings of multiple patents, the effects of demands known to the design community or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art, all in order to determine ***whether there was an apparent reason to combine the known elements*** in the fashion claimed by the patent at issue. To facilitate review, ***this analysis should be made explicit***.

Id. at 1396 (emphasis added); *see also In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006) ("[R]ejections on obviousness grounds cannot be sustained by mere conclusory

statements; instead there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.").

However, as explained above, ***there exists no apparent reason to combine any of these prior art references with other cited prior art to obtain a prestressed foam glass tile having, inter alia, both a prestress compression of 4,000 psi or greater and an average pore size of 1.0 mm or less.*** Nowhere in Jones et al., Elmer et al., or Ford, or any other prior art relied upon by the Examiner is there any explicit or even implicit reason or motivation for combining their teachings with other prior art to render the claimed ranges of both prestress compression ***and*** pore size obvious.

In view of the absence of any apparent reason for combining Jones et al., Elmer et al., and/or Ford with Zeinetz or other prior art to obtain the claimed invention of the rejected claims, the Examiner once again failed to establish a *prima facie* case of obviousness of Claims 42-47, 51-59 and 63-66. *See KSR*, 82 U.S.P.Q.2d at 1396; *In re Rouffet*, 149 F.3d 1350, 1357-58 (Fed. Cir. 1998) ("Because the Board did not explain the specific understanding or principle within the knowledge of a skilled artisan that would motivate one with no knowledge of [the] invention to make the combination, this court infers that the examiner selected these references with the assistance of hindsight. This court forbids the use of hindsight in the selection of references that comprise the case of obviousness.").

Accordingly, Appellant is entitled to reversal of the Examiner's final rejections and allowance of Claims 42-47, 51-59 and 63-66 on this Appeal over the cited prior art. *See In re Oetiker*, 977 F.2d at 1445.

VIII. CONCLUSION

For the reasons advanced above, Appellant respectfully submits that Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 are, as a matter of law, patentable over Grady, Ellis, Zeinetz, Williams et al., Blaha, Jones et al., Elmer et al. and Ford, either individually or in any combination thereof, and that all of the Examiner's final rejections of those Claims (*i.e.*, First, Second and Third Rejections) on this Appeal as set forth in the March 4, 2009 Office Action are in error. Accordingly, Appellant respectfully requests reversal of the final rejections from which this Appeal was taken and allowance of Claims 1, 5, 13, 14, 23, 27, 29-31, 37, 42-47, 51-59 and 63-66 over the prior art.

Respectfully submitted,

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CLAIMS APPENDIX

This Appendix contains a copy of the claims involved in this Appeal:

1. A prestressed foam glass tile wherein said tile has a compression strength of 10,000 psi or greater prior to being in a prestressed condition and a prestress compression of 4,000 psi or greater.

5. The prestressed foam glass tile of claim 1, wherein said prestress compression is 5000 psi or greater.

13. The prestressed foam glass tile of claim 1, wherein a tension member is under tension outside of said prestressed foam glass tile to provide said prestress compression.

14. The prestressed foam glass tile of claim 13, wherein said tension member-is comprised of a tension bolt.

23. A prestressed assembly for use in buildings or other structures comprising:

at least one prestressed foam glass tile, having a compression strength of 10,000 psi or greater prior to being in a prestressed condition and a prestress compression of 4,000 psi or greater;

at least two metal beams; and

one or more tension members

wherein said at least one prestressed foam glass tile is placed between said at least two metal beams and held in compression of at least 4,000 psi by said one or more tension members.

27. The prestressed assembly of claim 23, wherein said prestress compression of said at least one prestressed foam glass tile is 5000 psi or greater.

29. The prestressed assembly of claim 23, wherein said assembly is a column in a building.

30. The prestressed assembly of claim 23, wherein said metal beams are comprised of steel.

31. The prestressed assembly of claim 23, wherein said one or more tension members are comprised of tension bolts.

37. The prestressed assembly of claim 23, wherein said one or more tension members are not within said at least one prestressed foam glass tile.

42. A prestressed foam glass tile wherein said tile has a prestress compression of 4,000 psi or greater and an average pore size of 1.0 mm or less, wherein said average pore size is measured based on the distance between two farthest points of pore surface.

43. The prestressed foam glass tile of Claim 42, wherein said average pore size is 0.7 mm or less.

44. The prestressed foam glass tile of Claim 42, wherein said average pore size is 0.6 mm or less.

45. The prestressed foam glass tile of Claim 42, wherein said average pore size is 0.5 mm or less.

46. The prestressed foam glass tile of Claim 42, wherein said average pore size is 0.4 mm or less.

47. The prestressed foam glass tile of Claim 42, wherein said average pore size is 0.3 mm or less.

51. The prestressed foam glass tile of Claim 42, wherein said prestress compression is 5000 psi or greater.

52. The prestressed foam glass tile of Claim 42, wherein a tension member is under tension outside of said prestressed foam glass tile to provide said prestress compression.

53. The prestressed foam glass tile of Claim 52, wherein said tension member is comprised of a tension bolt.

54. A prestressed assembly for use in buildings or other structures comprising:

at least one prestressed foam glass tile, having a prestress compression of 4,000 psi or greater, and an average pore size of 1.0 mm or less, wherein said average pore size is measured based on the distance between two farthest points of pore surface;

at least two metal beams; and

one or more tension members

wherein said at least one prestressed foam glass tile is placed between said at least two metal beams and held in compression of at least 4,000 psi by said one or more tension members.

55. The prestressed assembly of Claim 54, wherein said average pore size of said at least one prestressed foam glass tiles is 0.7 mm or less.

56. The prestressed assembly of Claim 54, wherein said average pore size of said at least one prestressed foam glass tiles is 0.6 mm or less.

57. The prestressed assembly of Claim 54, wherein said average pore size of said at least one prestressed foam glass tiles is 0.5 mm or less.

58. The prestressed assembly of Claim 54, wherein said average pore size of said at least one prestressed foam glass tiles is 0.4 mm or less.

59. The prestressed assembly of Claim 54, wherein said average pore size of said at least one prestressed foam glass tiles is 0.3 mm or less.

63. The prestressed assembly of Claim 54, wherein said prestress compression of said at least one prestressed foam glass tile is 5000 psi or greater.

64. The prestressed assembly of Claim 54, wherein said metal beams are comprised of steel.

65. The prestressed assembly of Claim 54, wherein said one or more tension members are comprised of tension bolts.

66. The prestressed assembly of Claim 54, wherein said one or more tension members are not within said at least one prestressed foam glass tile.

EVIDENCE APPENDIX

This Appendix contains copies of the prior art references (1-8) relied upon by the Primary Examiner as to the grounds of the final rejection of the Claims on this Appeal.

This Appendix also contains a copy of the reference (9) which has been entered in the record by the Primary Examiner and cited by Appellant in this Appeal Brief. A copy of this reference was submitted by Appellant to the U.S. Patent Office along with the Supplemental Information Disclosure Statement dated October 19, 2005. The record indicates that it was considered by the Examiner in December 2005.

In addition, this Appendix includes a copy of the Declaration Under 37 C.F.R. § 1.132 (10) by Appellant and the inventor of the subject application, Dr. Pedro M. Buarque de Macedo, which was submitted to the U.S. Patent Office on May 2, 2007 as part of Appellant's response to the September 11, 2006 Office Action.

1. U.S. Patent No. 4,324,037 to Grady, II
2. U.S. Patent No. 3,430,397 to Ellis
3. U.S. Patent No. 3,292,316 to Zeinetz
4. U.S. Patent No. 4,124,365 to Williams et al.
5. U.S. Patent No. 3,056,184 to Blaha
6. U.S. Patent No. 3,459,565 to Jones et al.
7. U.S. Patent No. 3,592,619 to Elmer et al.
8. U.S. Patent No. 2,758,937 to Ford
9. EDWARD G. NAWY, PRESTRESSED CONCRETE: A FUNDAMENTAL APPROACH 8-13 (1989)
10. Appellant's Declaration Under 37 C.F.R. § 1.132 dated May 1, 2007

RELATED PROCEEDINGS APPENDIX

None

United States Patent [19]

Grady, II

[11] **4,324,037**

[45] **Apr. 13, 1982**

[54] **STRUCTURAL UNITS AND ARRAYS THEREFROM**

[76] Inventor: Clyde C. Grady, II, 3700 Garth Rd., Apt. 2101, Baytown, Tex. 77521

[21] Appl. No.: **828,312**

[22] Filed: **Aug. 29, 1977**

[51] **Int. Cl.**^{3} **B23P 21/00**

[52] **U.S. Cl.** **29/469**; 29/433; 52/227; 52/229; 52/585; 264/274

[58] **Field of Search** 29/433, 452, 469, 526, 29/527.1, 530; 249/38, 84, 168, 169, 188, 189; 52/227, 228, 229, 585, 587; 264/271, 274, 279

[56] **References Cited**

U.S. PATENT DOCUMENTS

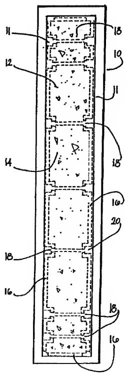
2,751,776	6/1956	Streblow et al.	52/228 X
2,902,721	9/1959	Heuer	264/274
2,971,295	2/1961	Reynolds	52/228 X
3,295,286	1/1967	Schaich	52/585 X
3,382,632	5/1968	Grofcsik	52/228
3,918,222	11/1975	Bahramian	29/452 X
3,962,088	6/1976	Kuhlenschmidt	52/227 X

Primary Examiner—Leon Gilden

[57] **ABSTRACT**

A building structural unit and its method of construction is disclosed. Additionally provided is a method for the building of structural arrays with a plurality of the structural units. The structural unit of the present invention provides an inner structural core portion having provided attached to the outer surface thereof load-distributing surfaces. Suitable attachment means can be provided in order to facilitate connection of a plurality of the individual units together forming a structural array such as a wall, slab, ceiling, column, or the like. The structural units can be fastened together by means of tension members such as for example threaded rods, with each individual unit being provided with bores therethrough through which the tension members or rods can pass. Bolted or like connections at the tension member ends bear upon the provided load distributing surface to complete the desired mating of the individual units. A method for connecting the units together in order to form the desired structural array allows each unit to be completely self supported structurally upon its connection to the previous unit or to the formed array itself. A first embodiment provides a substantially rectangular shaped structural unit, useful in wall construction (FIGS. 2 and 3); a second embodiment provides a diagonally interfacing unit, useful in the construction of slabs, ceilings and the like (FIGS. 4 and 5); a third embodiment also provides an alternative diagonally interfacing unit useful in slab and ceiling construction, a fourth embodiment provides a unit member suitable for column construction; in a fifth embodiment, a generally hexagonal unit structure is disclosed.

9 Claims, 13 Drawing Figures



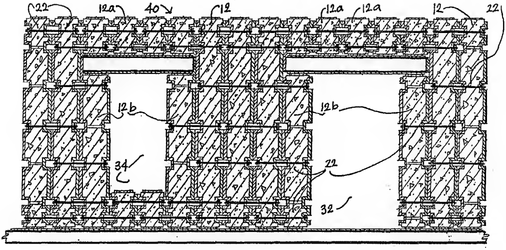


FIG 3

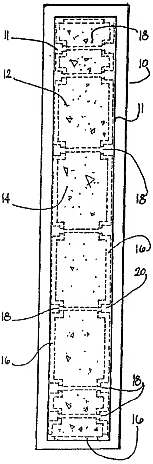


FIG 1

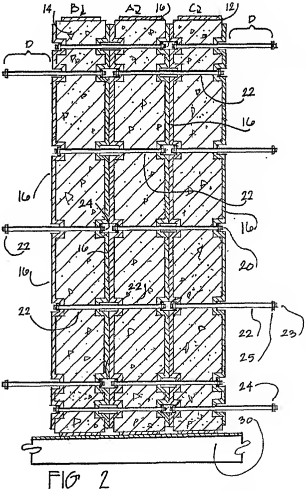


FIG 2

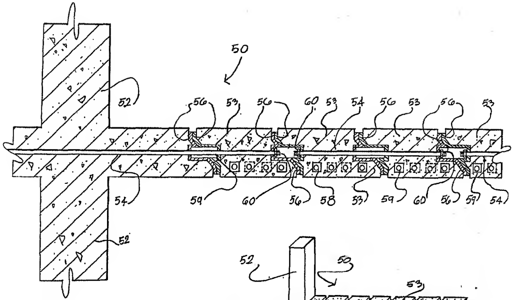


FIG 5

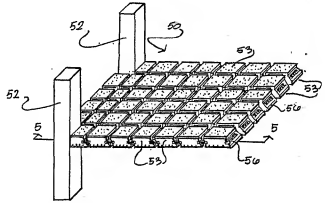


FIG 4

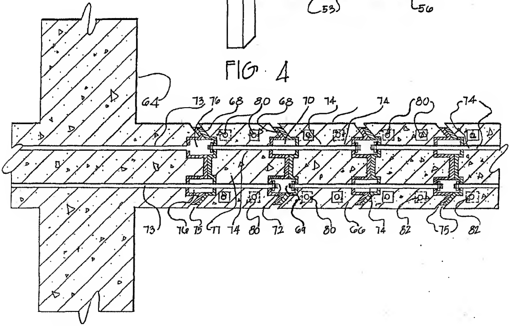


FIG 6

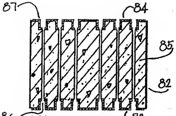


FIG 10

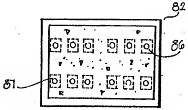


FIG 9

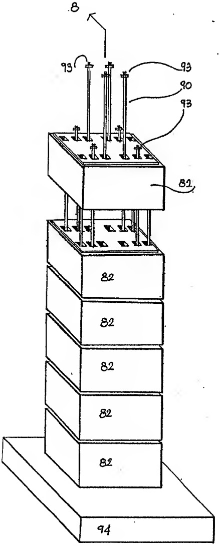


FIG 7

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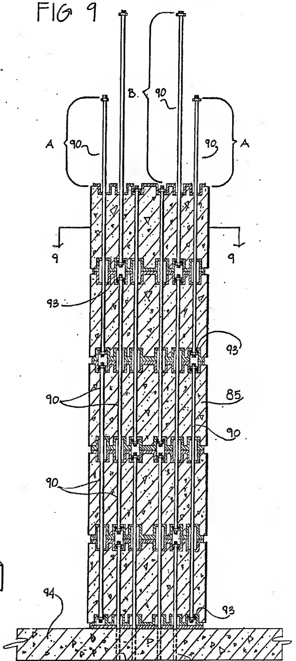


FIG 8

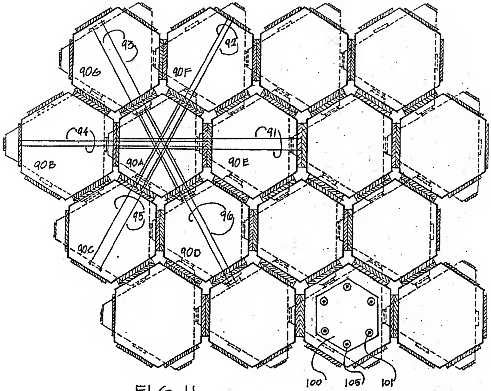


FIG 11

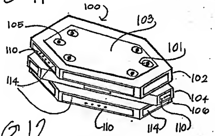


FIG 12

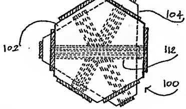


FIG 13

STRUCTURAL UNITS AND ARRAYS THEREFROM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to building elements or members, but more particularly the present invention relates to a composite structural unit, its method of construction, and a method of constructing or assembling the individual units of the present invention so as to form structural arrays such as for example walls, columns, slabs, ceilings and the like.

2. General Background

It is known to form structural building arrays comprised of a plurality of individual units held together in load bearing abutment to one another by means of overall tension members which extend through or otherwise connect all the individual units in a dimension of the assembled structural array. The tension members are constituted generally of iron, steel or like tensile members with externally threaded ends (or like suitable connections) which extend to the ends of the assemblies of the units such as by the use of plates, washers and nuts, or like end bearing connections. The so constructed unit can be tightly drawn together and handled as a complete structural load bearing unit. Such units are useful in the in situ construction of walls, pre-fabrication of walls, floor slabs, arches, beam and column forms, and the like.

Among the advantages offered by such structural units is that there exists no necessity of using grout, mortar, or like conventional connections between the units or rows of units. Thus the structure can be formed with a smooth, dry load bearing joint at any place and transported from that place of assembly to the location of its use as a complete load bearing self contained unit.

Whereas structural units of this type have generally attempted to solve the problem of providing a structurally sound unit which can be assembled and transported, or in fact assembled at the job site without the use of grout, and attentive labor, a significant deficiency nonetheless exists in the use of such structure units.

One problem which arises with structural units which are so connected in the prior art, is that point stresses often develop at the joints or faces of the units where these members are in abutment, these stress points often being effected after construction when the applied load is manifested. The points of strain set up within the units often cause chipping, cracking, or in fact fracture or failure. Such flaws can at least create an unsightly appearance and worse can result in a threatened stability and utility of the structure itself.

A further problem seen with many prior art structural units is that they require a substantial amount of initial bracing and secondary support to the arrays or individual building units themselves during construction and prior to the application of the tension members to the structure. Such a need for secondary support is time consuming, labor wasting, and expensive. Oftentimes, without the use of heavy construction equipment and construction crews, this type of secondary structural support is out of the question.

Some other prior art units are restricted to a single structural array by their very nature, and cannot be combined into several different forms as may be desired by the individual who is constructing a specific planned building.

It is accordingly an object of the present invention to provide a new and novel structural building unit wherein a structural core to the building unit is provided, having load-distributing surfaces thereon to which point stresses can be applied without significant damage.

Another object of the present invention is to provide a structural building unit which is particularly useful in structural concrete applications, such as reinforced concrete, poststressed concrete, concrete shells, and architectural applications.

A further object of the present invention is to provide a means to more evenly distribute the load stress to the joints of abutting individual structural members without the problem of fracture or cracking.

A further and more specific object of the present invention is to provide structural building units of such character which do not require the use of mortar to hold the units together and which have particular utility in the construction on site or offsite of structural arrays formed from a plurality of individual structural units such as concrete walls, floor slabs, arches, beams, columns, and the like.

A further object of the present invention is to provide a composite structural unit which is provided with means for attaching it to other like units in order to form an array, with the connection means therebetween being the only structural connection necessary in order to form a final and complete structural bond with the individual unit to the array to which it is being attached during construction itself—secondary structures and bracing being unnecessary.

Another object of the present invention is to provide a method of construction of a composite structural unit, which constructed unit requires no additional milling, filing or like refinement after its casting.

These objects and others are achieved in accordance with the present invention embodying an apparatus, or structural building unit, comprised of a inner structural material and there being provided thereon outer load-distributing surfaces to which connection means can be attached without the problem of point stresses creating cracks, chips, or the like.

3. Prior Art

The prior art discloses a number of patents which have been issued on various building systems which attempt to provide a final array of individual building units in order to form walls, ceilings, slabs and the like. A listing of some prior art systems which have been patented is listed in the following table.

Prior Art Patents		
U.S. Pat. No.	Inventor(s)	Issue Date
Re. 27,785	H. Kobayashi	Oct. 16, 1973
2,102,447	D. D. Whitacre	Dec. 14, 1937
2,684,589	A. Perreton	July 27, 1954
2,929,236	H. W. Steward et al	Mar. 22, 1960
3,145,502	D. Rubenstein	Aug. 25, 1964
3,173,226	A. Solnick	Mar. 16, 1965
3,260,025	C. Van Der Lely	July 12, 1966
3,378,969	G. K. Larger	Apr. 23, 1968

Many of the devices or systems of the prior art which have been patented provide various drawbacks in their attempt to solve the aforementioned problems, to which problems the present invention is directed and which

drawbacks and problems are solved by the present invention over the prior art.

U.S. Pat. No. 2,102,447 by Donald D. Whitacre provides a structural building system wherein there is the necessity to grind the contact surfaces between individual structural units prior to assembly. The present invention does not require the grinding or milling of the surfaces of the individual structural units prior to their use, but rather provides a method of construction by which the contact surfaces of the individual units are by their nature perfectly flat and aligned as is required before their use in forming an array.

The present invention provides a significant advantage over the prior art in that there is no necessity of the use of secondary structures or supplemental structures in order to support the array prior to the application of the tensioning members thereto. In the method of constructing the arrays of the present invention, the tension is applied with the addition of each structural unit and such tension member holds that individual structural unit in place without the use of secondary structures, secondary bars, or secondary supports in order to hold the unit until the entire structural unit can be tensioned. The Kobayashi patent, U.S. Pat. No. Re. 27,785 provides the use of such a supplemental structure until the concrete hardens. Such a device requires a secondary structure until the curing time of concrete gives it the desired strength.

U.S. Pat. No. 3,173,226 issued to Abraham Solnick requires the use of extra supportive framework.

In contrast to U.S. Pat. No. 3,145,502 issued to D. Rubenstein, in the present case of plates or surfaces made of plastic, the surface, if formed after the initial molding, is on the abutting surfaces not on the facing surfaces as in the Rubenstein patent.

The present invention does not require a complex system of rods which can only be stressed after an entire row of units is laid, such as is taught in the Perreton patent, U.S. Pat. No. 2,684,589.

U.S. Pat. No. 3,260,025, issued to C. Van Der Lely discloses the use of facings which are formed of a plastic material to make a seal. In the 3,260,025 patent, the object is to seal, not to distribute the load evenly over the contact surface as is the case with the present invention. The object of the present invention is to distribute the load and hence the facing material has different characteristics.

The rods with the present invention are not made continuous throughout the entire span as in the devices of the prior art, and do not transmit unequal loads with expansion and contraction effects of rods throughout a dimension of the entire structure.

Also a specific object is to provide a method of assembling the units whereby one unit is placed in position and means of applying compressive force to keep it in place is applied to that unit suitably by the application of tension to rods one end of which is anchored on a face of a unit already in place, that face being other than the one abutting the unit just positioned and the other end of the rod being attached to a face of the unit just positioned which is not identical to the abutting face of the unit just positioned.

Discussion of the Present Invention

Thus the present invention provides a structural unit construction which has inner structural load carrying capability, with an outer load-distributing surface which distributes the compressive load generated at the abutting surfaces of the individual structural units over a wider area, and transmits the loads through the interface formed between the facing of the structural unit and the face of the core material which forms the body of the structural unit, which is by the method of formation of the composite devoid of imperfections in mating interface which lead to point stresses.

By the use of hard or metal contact facings, the force is transferred from the core inner surface of the material which forms the structural unit to the metal surface of the contact plate which it must of necessity exactly match since the surface of the body of the structural unit was formed in contact with the facing. The force is then transferred from one outer metal surface to the outer surface of the metal or otherwise constituted facing of the abutting structural unit and then through the facing to the outer facing of the core body of the next structural unit. If there is unevenness of contact at the metal to metal interface the internal strength of the facing (metal) absorbs these stresses and distributes the force more evenly over the face of the core body. This ability of the facing becomes more and more important with the increase in compressive loads encountered with high tension in the tension rods and with greater height if the structural units are placed one atop the other as in the construction of columns or walls.

The present invention can be manufactured using structural units with clay as well as cement and like structurally sound materials, with the facings being manufactured of a suitable load-distributing material such as plastic, metal, and the like. The present invention provides such an individual structural unit which can be bound in face-to-face relationships in order to form constructive arrays. The units are self supported upon attachment using a suitable tension means such as an elongated metal rod, or a plurality thereof, preferably constituted of iron, steel, or like tensile material which is passed through a plurality of openings or perforations through the units themselves. The end portions of the rods can be externally threaded and adapted for threadable engagement with a plate, nut, or the like; however, any suitable means of connecting units together by affixing the end portions of the rod can be used.

BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the nature and objects of the present invention, reference should be had to the following detailed description, taken in conjunction with the accompanying drawings, in which like parts are given like reference numerals and wherein:

FIG. 1 depicts a top plan view of a mold used in the method of construction of the preferred embodiment of the composite unit apparatus of the present invention-the composite unit shown therein in phantom lines;

FIG. 2 depicts a composite structural building array formed from a plurality of units of a first embodiment of the present invention, the array being characterized of one modular unit which constitutes the building described by reference to FIG. 3;

FIG. 3 is an elevational view of various sizes of composite units of the first embodiment of the present invention;

FIG. 4 is a perspective view of a slab section formed from an assembly of the second embodiment of the composite unit structure of the present invention held together by suitable tensioning means;

FIG. 5 depicts a cross sectional view taken along lines 5—5 of FIG. 4;

FIG. 6 is a cross sectional view of a typical slab formation using the third embodiment of the composite unit structure of the present invention;

FIG. 7 is a perspective view illustrating a fourth embodiment of the composite unit structure of the present invention being attached to form a structural column;

FIG. 8 is a sectional view taken along lines 8—8 of FIG. 7;

FIG. 9 is a sectional view taken along lines 9—9 of FIG. 8;

FIG. 10 is a side elevational view and partial section of a single isolated unit of the fourth embodiment of the composite unit structure of the present invention as employed in the structural array depicted by reference to FIGS. 7 and 8;

FIG. 11 depicts in plan a slab formed by members of a fifth alternative embodiment of the unit of the present invention;

FIG. 12 is a perspective view of a single unit of the alternative embodiment of the apparatus of the present invention as forms of the structure depicted by reference to FIG. 11; and

FIG. 13 is a top sectional view of the unit of FIGS. 11 and 12.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a preferred embodiment of the mold 10 of the present invention which can be used to manufacture units 12 in accordance with the teaching of the present invention. As can best be seen by an inspection of FIG. 1, there is provided a shaped mold 10 having inner walls defining a shape corresponding to the desired shape of the individual unit 12 to be formed.

In FIG. 1, there is shown in phantom lines composite unit 12 which is comprised generally of an inner structural material 14 and outer load-distributing surfaces in the form of plates 16.

As can be seen in FIG. 1, in order to construct composite unit 12, outer load-distributing plates 16 are first placed in a desired position along the inner walls 11 of mold 10 such that when a suitable flowable material such as concrete, plastic, clay or the like is added to form inner core 14, it will exactly conform to the space provided between the load-distributing plates 16. If the mold 10 is properly constructed, inner walls 11 will act as a "jig" which will exactly position load-distributing plates 16 so that their outer surfaces 17 will not require additional filing or milling before use. The surfaces will easily fit together in face-to-face relationship, being compatible when several units 12 are combined to form an array. The connection or adhesion of plates 16 to unit 12 can be augmented using projections (not shown) attached to plate 16 which would act as anchors when inner core 14 "sets." Any suitable chemical bonding agent could likewise be used to augment the adhesion of the load-distributing plates to the structural core. Indeed, it is also possible, though time consuming to apply the load-distributing plates after the structural core material has "set" if the chemical bonding agent has the ability to withstand the compressive loads and, like the structural core material, at some point during or following its application, flows to conform to the surfaces which it bonds, thus again not forming point stresses.

A further inspection of FIG. 1 will reveal the presence of a plurality of bores 18 which are provided through the center portion of unit 12. These bores 18 form openings through which tension means (which can be in the form of elongated metal rods) can pass so as to eventually fasten a plurality of units 12 together. There is further provided as is shown in FIG. 1, a recess 20 on the opposite ends of each bore 18 which provides an enlarged area to facilitate the location of a suitable fastener such as a bolt, or the like.

FIGS. 2 and 3 illustrate the use of completed composite units 12 to form a structural array such as a wall or the like. In FIG. 2, there can be seen three units 12 as is shown during their construction in FIG. 1. The completed units 12, it will be noted from FIG. 2, do not require any additional milling, planing, or surface treatment, in order that they may mate together in a perfect fit upon assembly. In FIG. 2, units 12 can be seen each having load bearing plates 16 on their load bearing surfaces. The inner core 14 is shown having been cast and hardened into the proper position as was illustrated in FIG. 1 with mold 10. Now, the inner core 14 is suitably hardened and has desirable compressive strength characteristics which of course are designed after considering the desired load carrying characteristics of the structure being built.

In FIG. 2, there is seen a plurality of tension members which are in the form of connecting rods 22. In FIG. 2, each connecting rod 22 can be an elongated rod of a material such as steel, iron, or like suitable tensile material. Rods 22 can be threaded being provided with threads 23 at their respective end portions as is known in the art. There can further be provided bolts 24 which threadably engage and attach to connecting rods 22 at threads 23. If desirable, washers 25 can be provided which are placed between bolt 24 and load bearing plates 16. It will be seen, that when connecting rod 22 is in its proper position, connecting together any two of units 12, bolts 24 will assume a flush position within recess 20 thereby not interfering with the addition of other units as the construction continues. The connection can be completed with a desired tension or stress to rod 22 by use of a connectional torque wrench to guarantee uniformity and consistency throughout the structure.

When constructing the device in this manner, it can be seen that by beginning with a single unit (designated as unit "A" in FIG. 2) it is easy to add additional units (such as "B" and "C" in FIG. 2) without any additional structural support other than rods 22. Thus, if one began by placement of unit A resting against a base slab 30 as is shown in FIG. 2, unit B could be added and attached thereto permanently and structurally by connecting rods 22 as is shown. In FIG. 2, every other bore 18 in unit 12 is provided with a rod 22 to connect units A and B together. Note, however, that in the alternate openings 18 the connecting rods 22 are connected only to unit B and project outwardly therefrom a distance which will allow the addition of a further unit when it is added after A and B are secured together. Such an arrangement is important, because each unit is completely affixed to the structural array upon bolting, but additional units 12 can always be added if desired. It is also important that the aligned tensile rods are not connected one to the other because unequal stresses are created within the array decreasing its strength.

In a like manner, there can be seen at the connection between units A and C, the use of every other or alter-

nating connecting rods 22 in order to form the structural connection between A and C, with the alternate or other rods 22 being connected to C only and projecting a distance out therefrom in order to add another composite unit. The projection distance of the rods which will be used to add additional units 12 is designated by the letter D in FIG. 2.

Alternatively, the rods 22 need not be placed within unit C so that they project a distance D for the attachment of additional units 12, not shown. Instead, the additional unit 12, not shown, may be placed in abutment with unit C and then the rods 16 which attach it to unit C may be inserted through holes 18 and by suitable means anchored or attached at one end to the facing 16 of unit C which contacts facing 16 of unit A and attached at the other end to the vertical facing 16 of the unit 12, not shown, which is not in contact with a facing 16 of unit C.

FIG. 3 illustrates a structural array which can be for example a wall, and is designated generally by the numeral 40 in FIG. 3. There it can be seen that array 40 is constructed of a plurality of individual units 12, each being attached by means of a plurality of connecting rods 22 which can be threadably mounted (or like suitable connection) to the units as was described more fully above. Note in FIG. 2 that each alternating rod 22 is "staggered" so that there will always be a projecting amount of rod 22 beyond the surface of the previously connected unit so that additional units 12 can be added as needed. In FIG. 3, it can be seen that units 12 can be of varying dimensions within the teaching of this invention. Note smaller units 12*a* as they appear above door 32 and window 34 in FIG. 3. Likewise, units 12*b* are of a shorter dimension than units 12 which are substantially the height of array 40 which forms a wall in FIG. 3.

With the method of construction as described more fully above, it should be appreciated that there is no necessity for extra bracing or like supplemental support in order to apply the tensioning members 22 and connect additional units 12 to the array. To the contrary, each unit 12 when added to the structure and fastened into place using connections 22 is totally and completely structurally sound with the array 40 as a whole and forms its structural part thereof without necessity of grout, concrete, supplemental supports, or the like, thus offering a significant economic advantage over the prior art with a significantly decreased possibility of the creation of point stresses found in the prior art in a more economic manner than in the prior art.

However, grout or mortar may be injected into the void area of the bores 18 between the rods and the wall of the bore to give an additional measure of strength if desired as is known in the art. However, such is not necessary and renders the structure more permanent.

Thus, it can be seen that utilizing the apparatus and method of construction of the present invention there can be constructed an array 40 of units 12 to form a wall simply by use of connecting rods 22 within the teaching of the present invention.

FIGS. 4 and 5 illustrate a second embodiment of the apparatus of the present invention. In FIG. 5, there can be seen a slab 50 constructed between columns 52. Slab 50 can be constructed of a plurality of units 53 using connecting rods 54. Units 54 in the second embodiment have generally diagonal load-distributing plates 56 which aid in the structural integrity of slab 50 which is subjected to high shearing forces as is apparent to one skilled in the art.

The use of diagonal plates 56 illustrates but a second embodiment of the teaching of the present invention, though the method of constructing units 53 would be by use of a mold 10 as was described more fully above and with reference to FIG. 1. The mold 10 used to cast units 53 would provide inner walls 11 which would create a "jig" effect to orient bearing plates 56 into a desired spaced relationship so that no additional milling, cutting, or forming of plates 56 would be required when the casting was completed. Openings would be provided through structural units 53 in the same manner as they were provided in the first embodiment discussed above so that connecting rods 54 could be "staggered" enabling the assembly of slab 50 without the necessity of extra structural supports, external bracing, grout, concrete, or the like. There is seen in FIG. 5 a plurality of openings 58 through which tensile connectors could pass in a direction traverse to the rods 54 shown in FIG. 5. Such traverse openings 58 would provide connection to slab 50 in a direction normal to the connection rods 54 shown in FIG. 5 so that the slab 50 could be braced in both directions as would be desirable. Note that in FIG. 5 there is shown recesses 59, 59' which allow a space into which bolts 60 or like connections can be placed so as not to interfere with the interface between successive structural units 53.

FIG. 6 illustrates a third embodiment of the composite structural unit of the present invention. The embodiment shown in FIG. 6 provides a slab structure designated generally as 62 attached to column 64 which utilizes a plurality of structural units 66 which are constructed within the teaching of the present invention using a suitable mold 10 giving the desired structural unit geometry. Units 66 provide diagonal load-distributing plates 68, each plate provided with a pair of recesses 69, 70 which can be used for the placement of a bolt 72 or like connective member at the end of a tension rod 74 as shown in the drawings. In FIG. 6, it can be seen that there is likewise provided a second cooperative bearing plate 75 which abuts and fits comfortably against plate 68 so as to form a mate therewith. Likewise, bearing plate 75 is provided with recesses 76 for the accompanyment of bolt heads 72 or like connectors. In the embodiment shown in FIG. 6, there can be provided two connective rods 74 in separate horizontal layers as is illustrated in the drawing. In the embodiment shown in FIG. 6, connective rods 74 could be of any high tensile material such as steel or the like, and the inner core 77 of units 66 could be formed of concrete for example. There is likewise provided openings 80 traverse to that direction of rods 74 in FIG. 6. Openings 80 and corresponding recesses 82 could be used to accompany rods 74 and bolts 72 respectively within the teaching of the present invention.

In order to suitably anchor the first unit as added to column 64, there could be provided an initial anchor rod 73 as is shown in the drawing, with the length of rod 73 being "developed" by its embedment into the concrete column 64 a desired distance as is known in the art. In FIG. 6 there is an alternating arrangement of rods 74 in the plane of the drawing. However, it should be understood that the alternating arrangement, which allows subsequent units to be added to the array, may be in a direction normal to the rods 74 shown in FIG. 6, the same effect being achieved.

FIGS. 7-10 illustrate a fourth embodiment of the composite structural unit of the present invention. There can be seen in FIGS. 7-10 a block 82 having load-distributing plates 83, 84, respectively, on its lower and upper portions as viewed in FIG. 10. Unit 82 would likewise be formed having an inner core 85 of a suitable material having the necessary compressive strength, and plates 83, 84 providing a surface which would have load-distributing characteristics necessary in order to transmit the compressive forces generated by connecting rods 90 to unit 82. In FIG. 7, there can be seen a column 92 constructed of a plurality of units 82. Column 92 would be merely a single array having individual units 82 "stacked" thereon as shown in the drawings. There would be provided a plurality of openings 86 through which connecting rods 90 could be placed as is shown best in FIGS. 7 and 8. Likewise, as with the previous embodiments of the present invention, there could be provided recesses 87 which would provide a space for bolts 93 which could be threadably connectable to the end portions of rods 90.

FIG. 8 helps illustrate the method of construction of the present invention to construct column 92 of FIG. 7. In FIG. 8 there is seen a base slab 94 which has embedded therein a plurality of connectors 90 so as to form a spot for "beginning" column 92. After the first structural unit is placed over the initial rods 90, successive units can be added by "staggering" the rods 90 so as to always provide an exposed portions "A" and "B" of rod 90 on units 82 as desired. It is within the teaching of the present invention that the pattern may be altered so that the individual rods 90 and the connecting rods of the other embodiment may be of sufficient length to pass through any number of structural units less than the number of structural units required for the entire eventual span creating a slightly different but basically similar interlocking pattern although FIG. 8 shows that number to be three. Note in FIG. 8 there are provided rods 90 which project a distance A above the uppermost unit 82. These rods 90 which project a distance A, would initially bolt or attach and hold the next unit added to the stack, whereas there is also provided rods 90 which project a second distance B above the last added unit shown in FIG. 8. When a second unit were to be added to the stack as shown in FIG. 8, the rods which project a distance B would be utilized to secure that particular unit into its position. Thus, there can be seen a method of construction shown with the column of FIGS. 7 and 8 which provides a connection of each successive unit to the column, with each connection forming a complete integral structural connection with the previous unit, there being no need for supplemental bracing, or other structural supports.

As in the first embodiment of the present invention and in all embodiments of the present invention the tensile rods 90 of FIGS. 7 and 8 need not project distances B and A, but may be inserted as required to attached successive structural units 82 to the columnar array 92 after placement of a structural unit in position on the columnar array.

FIG. 9 illustrates a top view of the column shown in FIG. 8, whereby it can be seen a plurality of openings 86 through which rods 90 can pass, and there can also be seen recesses 87.

FIGS. 11 through 13 illustrate a fifth embodiment of the apparatus of the present invention. In FIG. 12, hexagonal unit 100 is made to appear as a plurality of stacked solid layers 102, 104, and 106. It should be understood, however, that the exemplary number of three (3) layers provided to unit 100 as shown in FIG. 11 is not absolute. Each layer represents generally a line of force through which connections can be made through various abutting units so as to form an array as shown in FIG. 12, thus varying numbers of layers 102, 104, 106 could be provided.

In FIG. 12, there can be seen connection holes 110 through which suitable connecting rods (not shown) can be attached. Bearing plates 114 are provided at the outer edges of each layer 102, 104, 106 as is the case with previous units within the teaching of the present invention as was described more fully heretofore. The units 100 can be connected to form an array as shown in FIG. 11, with the rods 112 being alternatively arranged so that each unit 100 can be securely connected to the preceding unit 100 or to the array in the manner as depicted for the single structural unit 90A in FIG. 11. In FIG. 11, unit 90A is connected at its edges to units 90B, 90C, 90D, 90E, 90F and 90G. Tensile connectors 91, 92, 93, 94, 95 and 96 secure the array as is shown in FIG. 11. Thus an interlocking repeating pattern is formed. In FIG. 12, there is shown attached to the individual hexagonal structural unit 100 a load-distributing plate 103 with holes 101 passing through it and the structural core of the unit 100 with recesses 105 which allow the usage of the structural unit at the same time as both an element in a vertical array of a column, similar to the fourth embodiment of the invention described in conjunction with FIGS. 7 through 9, and an element in the horizontal two-dimensional array of a slab. Thus, the horizontal two-dimensional array of the slab and the one dimensional array of a column are integrally connected.

The structural units 100 can be formed much in the same way as the previous teachings of this application, in which a mold 10 is utilized having geometrically desirably arranged inner walls 11 to which walls there can be affixed bearing plates 114 prior to the addition of a desired flowable "setting" material. When the setting material hardens (for example in 28 days or so with concrete), the mold can be removed and the unit is ready for its operational use in a structural array or the like.

Because many varying and different embodiments may be made within the scope of the inventive concept herein taught, and because many modifications may be made in the embodiments herein detailed in accordance with the descriptive requirements of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in a limiting sense.

What is claimed as invention is:

1. A method of constructing an array comprising the steps of:

a. providing a plurality of composite structural units, each of said structural units comprising
   (i) an inner structural core of cast material;
   (ii) a plurality of load-distributing plates integrally attached during casting to said core, each of said plates being substantially hard to resist fracture, and having internal strength sufficient to substantially dissipate point stresses there being provided a plurality of holes through said core and said attached plates, each of said plates providing a mating face for contacting the face of an adjacent attached unit;
   (iii) tension means extending through said holes for holding two of said units tightly together in face-to-face relationship forming a structural array;

b. placing a first and a second of said structural units together in a desired array;

c. applying a tensile connector to the first and second units, perfecting a connection;

d. applying a second tensile connector to the second unit;

e. placing a third structure unit in face-to-face relationship with the second structural unit; and

f. perfecting a connection between the second and third structural unit using the second tensile connector.

2. A method of constructing an array comprising the steps of:

a. providing a plurality of composite structural units, each of said structural units comprising

(i) an inner structural core of cast material;

(ii) a plurality of load bearing plates integrally attached during casting to said core, each of said plates being substantially hard to resist fracture, and providing internal strength to substantially dissipate point stresses, there being provided a plurality of holes through said core and said attached plates, said plates providing a mating face for contacting the face of an adjacent attached unit:

(iii) tension means extending through said holes for holding two of said units tightly together in face-to-face relationship forming a structural array;

b. assembling a plurality of the composite units to form a structural row with each composite unit abutting the adjacent unit at its load bearing plate; and

c. applying tensile force connectors to the units, each tensile connector stressing a number of units less than the total number of units forming the row.

3. A method of constructing a structural array comprising the steps of:

a. providing a plurality of individual structural units, each of the units having an inner structural core of cast material and an outer integrally connected load distributing bearing plate, the bearing plates being connected to the inner core by casting at the inner core-bearing plate interface;

b. contacting two of the structural units together at the load distributing bearing plates;

c. forming a tensile connection between the two contacted structural units; and

d. adding additional structural units to the previously connected unit array, each additional unit being connected to the previously added unit by a tensile connecting member, which member stresses only the previously added unit and the added unit.

4. The method of claim 3 wherein in step "a" each provided structural unit is substantially rectangular and having two or more parallel, integrally connected load bearing plates.

5. The method of claim 3 wherein the array to be constructed is a wall, and in step "a," each structural unit is a vertically oriented unit having vertical side load distributing bearing plates.

6. The method of claim 3 wherein the array to be constructed is a column, and in step "a," each structural unit has upper and lower load distributing bearing plates.

7. The method of claim 3 wherein the array to be constructed is a slab, and in step "a," each structural unit is a horizontally oriented unit having generally vertical side load distributing bearing plates.

8. The method of claim 3 wherein in step "c" the tensile connection is formed between two contacted structural units using tensile connecting rods.

9. The method of claim 3 wherein in step "d" each tensile connecting member stresses at least two structural units, but less than the total number of added structural units.

* * * * *

March 4, 1969 J. P. ELLIS 3,430,397

TWO-WAY WALL BRACE

Filed Feb. 6, 1968

Fig. 1.

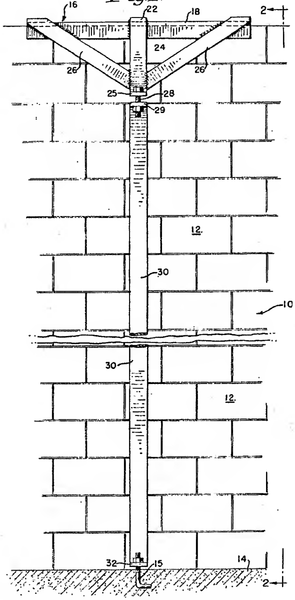


Fig. 2.

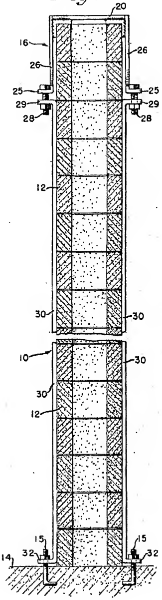
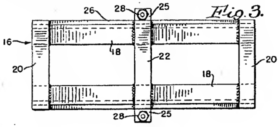


Fig. 3.



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TWO-WAY WALL BRACE
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Filed Feb. 6, 1968, Ser. No. 703,457
U.S. Cl. 52—227 1 Claim
Int. Cl. E04c *5/08, 3/10*

ABSTRACT OF THE DISCLOSURE

A tension strut device adapted to be applied to a building wall experiencing either inwardly or outwardly bowing forces applied thereagainst; said device comprising length-adjustable strut members running vertically along the opposite sides of the wall and interconnected across the top of the wall by a cap device; each strut member having hook means at its bottom end for hooking said device to ground anchor bolts or the like; the device being thereby adapted to apply compression forces to the wall resulting in forces tending to keep the wall rigid against forces applied thereto from either side of the wall.

The invention is adapted for use in connection with any brick or stone or concrete building wall; swim pool wall; or other fabricated wall which is subjected to lateral bulging forces. Such forces are typically encountered in relatively long straight wall fabrications which are exposed to storm wind pressures which on occasions will tend to blow the wall inwardly or out.

Whereas a variety of "pilaster" type brace devices have been previously suggested for such purposes, it is a primary object of the present invention to provide an improved and structurally simple brace device for brick or block walls or the like, which may be easily applied thereto (either during construction of the wall or at some later time) and which will effectively brace the wall against lateral bulging and/or collapse.

Another object is to provide an improved brace device as aforesaid which compactly nests against the wall and involves no substantial protuberances beyond the general profile of the wall structure, per se.

Other objects and advantages of the invention will be apparent from the following specification and the accompanying drawing, wherein:

FIG. 1 is a side elevational view of a concrete block type wall showing a brace device of the invention in operative position;

FIG. 2 is a fragmentary sectional view, taken as suggested by line 2—2 of FIG. 1; and

FIG. 3 is a top plan view of the brace device of FIG. 1.

By way of example, the invention is illustrated and described in detail hereinafter as being applied to a typical cement block wall construction designated generally at 10. However, it is to be understood that the "blocks" 12 may alternatively be of brick, or cut stone, or the like; and either "dry"-stacked or cemented together. The wall footing or foundation is illustrated at 14 and includes anchor bolts 15 embedded therein.

As shown herein, a brace device of the invention may be constructed to include a wall cap member 16 formed of two parallel angle irons 18—18 cross-braced by end

strap irons 20—20 and a center iron 22 which is inverted U-shaped and includes downwardly extending legs 24—24, terminating at their lower ends in right-angle flange portions 25. Diagonal braces 26 are welded or otherwise fixed to interconnect the ends of the angles 18 to the lower ends of the center iron 22 to complete the fabrication of a rigid "saddle" device for the top of the wall as shown. The flange portions 25—25 of the main strap member 22 are bored to accommodate bolts 28—28 which also engage the top flange portions 29—29 of corresponding pull strap members 30—30 which are dimensioned so as to lie flatwise against the sides of the wall 10. Right-angle flange devices are formed at the lower ends of the strap members 30—30 to engage the anchor bolts 15 extending upwardly from the wall foundation. It will be appreciated, of course, that in lieu of metal strips as indicated at 30—30, any other suitable tension applying device may be employed such as chains or steel cables, or the like.

Thus it will be appreciated, particularly by reference to FIG. 2 of the drawing herewith, that when the brace device of the invention is applied to a wall structure as shown herein the tension adjustment bolts 28—28 may then be actuated to apply to the system any desired degree of tensioning; and differentially if preferred to suit different problems. The tension adjustments of the system may be effected of course either by applying a wrench to the heads of the bolts 28 or by applying a wrench to the nuts, or both; but in any case by a simple screw-threading adjustment of the device the tension forces applied by the system may be readily regulated to suit the requirements of any situation. By virtue of this arrangement the tension forces exerted by the system of the invention are primarily applied as compression forces acting through the innermost vertical edges of the building blocks comprising the wall. However, this tends to rock contiguous blocks, one relative to the other; their innermost edges operating as fulcrum surfaces. Thus, it will be seen that the device applies to the wall structure a combination of force effects including a substantial component tending to bow the wall in any desired direction and in direct opposition to forces which would otherwise tend to bow the wall.

It is of course to be understood that whereas only one form of the invention has been illustrated and described in detail hereinabove, various changes may be made therein without departing from the spirit of the invention or the scope of the following claim.

What I claim as my invention is:

1. In combination, a building wall comprising a vertically stacked series of building wall blocks extending upwardly from a rigid footing having anchor bolts extending therefrom, and a brace device therefor,

said brace device including a saddle member of inverted U-shaped form disposed to straddle at least the uppermost course of building blocks,

said saddle member comprising a pair of parallel disposed angle irons embracing a plurality of said building blocks along the opposite top side corner portions of said wall, and cross brace members extending transversely thereof and fixed to said angle irons and having leg portions depending downwardly therefrom along opposite sides of the wall and terminating in detachable connection portions,

and a pair of tension transmitting members disposed respectively vertically along opposite sides of the

wall, each of said tension members having means at its lower end detachably connected to one of said anchor bolts and terminating at its upper end in means coupling it to one of said detachable connection portions,

said saddle and tension transmitting members being dimentioned and arranged so that said tension transmitting members may be selectively tautened so as to apply to opposite sides of said saddle member any desired tension forces to stabilize the wall against laterally applied forces tending to bow the wall.

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SELF-SUPPORTING ROOF

Filed Sept. 26, 1961 5 Sheets-Sheet 1

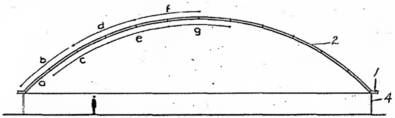

FIG. 2

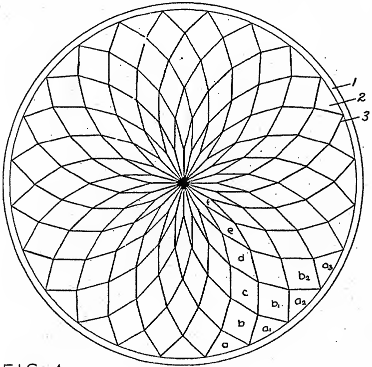

FIG. 1

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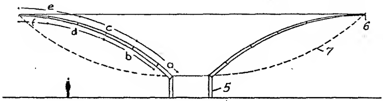

FIG. 4

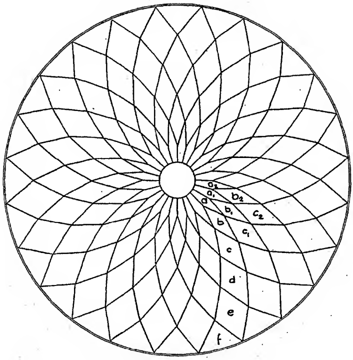

FIG. 3

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Dec. 20, 1966 B. O. ZEINETZ 3,292,316

SELF-SUPPORTING ROOF

Filed Sept. 26, 1961 5 Sheets-Sheet 3

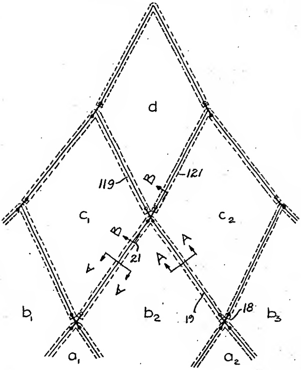

FIG. 5

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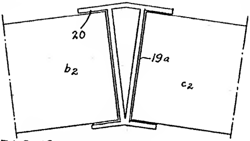

FIG. 12 A–A

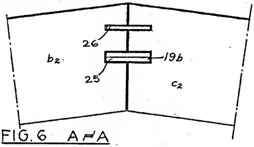

FIG. 6 A–A

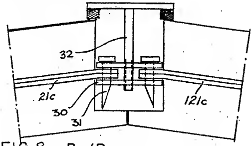

FIG. 8 B–B

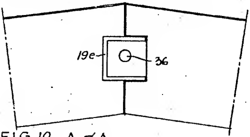

FIG. 10 A–A

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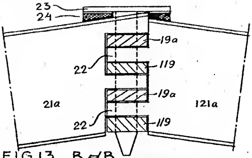

FIG.13 B-B

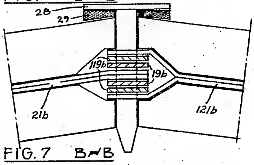

FIG. 7 B-B

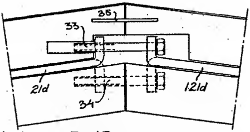

FIG. 9 B-B

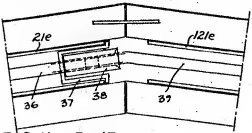

FIG.11 B-B

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United States Patent Office

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Patented Dec. 20, 1966

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3,292,316
SELF-SUPPORTING ROOF

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Claims priority, application Sweden, Oct. 1, 1960, 9,389/60; Mar. 23, 1961, 3,104/61
12 Claims. (Cl. 52—81)

The invention relates to roofs of buildings.

More particularly, this invention relates to self-supporting building roofs of the shell, cupola or vault types.

Still more particularly my invention relates to roof structures for larger spans which are nearest comparable with the shell structures of the type erected for example by the well-known Italian Luigi Nervi or the lattice-work cupolas erected by the American Buck Fuller and others.

The known lattice-work cupola is built up of bars and junctions often disposed in various geometrical patterns. Said frame is subsequently at the place of erection covered with protecting and insulating material which work often must be done highly above the ground and which, in order to be performed with a minimum of risk, calls for erection of high scaffolds or stagings.

The shell structures of Nervi, which are of concrete, have generally been moulded at the place of erection which requires a very extensive shaping work. In some cases said structures have been mounted in the form of a prefabricated frame, and the covering and insulating roof material has been mounted at the place of erection under the same unfavourable conditions as are experienced in the erection of the lattice-work cupolas.

One main object of the present invention is to provide a system for erecting self-supporting shell, cupola, and vault roofs which comports many marked advantages over the prior art.

Another object of the invention is to provide a roof construction consisting of elements constituting both the supporting frame and the covering roof surface and the insulation. This construction has the advantage that the whole roof structure can be manufactured in a finished shape at a plant whereby the production is highly simplified and the costs thereof are considerably reduced. A further advantage is that the complicated erection of scaffolds or stagings at the place of erection is almost completely avoided.

A further object of the invention is to provide roof elements formed so as by part-engaging one another to impart to the structure sufficient strength for taking up irregularly divided loads.

A still further object of the invention is to provide a structure which when applied to cupola roofs makes elements already mounted to constitute a support for additional elements whereby the valuable advantage is obtained that no stagings need to be erected for the following mounting operation.

Still a further object of the invention is to provide roof elements for buildings the entire covering surface of the roof structure of which can be used for taking up crushing stresses produced by the own weight of the roof and additional loads accumulated thereon.

Further objects and advantages of the invention will become apparent from the following description, considered in connection with the accompanying drawings which form part of this specification and of which:

FIGS. 1 and 3 are top views of roofs constructed according to the invention.

FIGS. 2 and 4 are vertical sections through the roofs shown in FIGS. 1 and 3 respectively.

FIG. 5 is an elevational view of groups of adjacent elements forming part of a roof according to the invention, and individually shaped differently.

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FIG. 5 is a diagrammatic top view of a part of a roof constructed according to the invention from a plurality of adjacent interconnected elements. FIGS. 6, 10 and 12 are sections following lines A—A, and FIGS. 7, 8, 9 and 11 are sections following lines B—B in FIG. 5 and represent various coupling means for abutting elements.

Referring to the drawings, FIG. 1 is a top view of a building constructed according to the invention when finally erected. The building has a roof comprising an angular edge frame 1 limiting a cupola-formed shell composed of a plurality of elements 2 meeting one another in joints 3. The elements 2 are disposed in different series denoted by *a*, *b*, *c*, *d*, *e* and *f*. The elements in the same series are preferably identical as is indicated in FIGURE 1 by index numbers such as a_1, a_2, a_3, b_1, b_2, etc.

In a vertical section the building preferably is formed as is shown in FIG. 2. In the example shown in said figure the edge frame 1 rests on columns 4. It may also rest on base structures of other shape or directly on the ground. The figure also indicates how the elements in the various series project past one another so as to impart desired good structural strength to the finished shell.

The building with its roof is preferably erected in the following manner. The columns 4 are raised. On said columns the edge frame is placed. Said frame may consist of several part elements. If desired the edge frame may be provided additionally with an annular girder adapted to take up the horizontal component of the compressive force resulting from the load acting on, and the own weight of the cupola roof.

The first series of elements denoted by *a* may have a triangular form and is secured to the edge frame by means of a suitable coupling device. The following series of elements *b* may have a rhombic form. One element of said series *b* is secured between two elements of the series *a* by wedging one projecting tongue thereof between two elements of the series *a* and is kept in position by means of a suitable coupling device which will be described more in detail later in this specification. The entire series of elements *b* when mounted finally forms together with the elements of the series *a* an annular shell structure capable of taking up horizontally acting compressive forces which renders the shell self-supporting and thus makes scaffolds or staging unnecessary.

The series of elements *c* is mounted in a similar manner as the series of elements *b*. Together with the series *a* and *b* the series *c* forms a self-supporting shell. Remaining series of elements denoted by *d*, *e*, and *f*, are mounted in a corresponding manner until the whole shell is finished. If desired, the last series or the last two or three ones may be replaced by a minor cupola or like member adapted to admit light into the interior of the cupola.

FIG. 3 shows a funnel-shaped building constructed according to the invention. This embodiment of the invention may be mounted on a tubular base 5. The first series of elements *a* is mounted on the top of said tubular base. The subsequent series of elements *b*, *c*, *d*, *e* and *f* are mounted in a similar manner as in the embodiment shown in FIGS. 1 and 2. The erection is finished by stretching an annular girder 6 around said series *f* of elements which girder is destined to produce the horizontally acting force keeping the shell together.

The funnel-shaped building may according to an alternative embodiment be curved in another manner as is indicated in FIGURE 4 by dashed line 7.

A shell-formed building embodying the invention may be made of elements formed in various manners. One example is shown in FIG. 5. The elements, some of which are represented and denoted by b_1, c_1, c_2 and d_1 respectively, have the form of rhomb-shaped slabs abutting edge to edge.

FIG. 5 is an elevational view of several elements kept together adjacent one another by means of coupling devices indicated generally by reference numeral **18**. The elements are formed along their lateral edge portions with unbroken profile members **19**, **119**, **21** and **121** adapted to fit the abutting lateral edge portions of adjacent elements. When assembling these elements, the edges of an adjacent element are inserted into the profile member of the element or elements already mounted so that in the finished roof the elements are mutually connected along rows of interengaging profiles which keep each element in wedged engagement with the adjacent elements and prevents them from being forced out of engagement when the building is subjected, for example, to the attack of winds exerting a sucking effect on the roof. The rows of interengaging profile members also render possible the prestressing of the shell of the cupola.

FIG. 12 is an example of a joint between two adjacent elements based on a profile member **19*a*** having H shape. The flanges **20** of the profile member **19*a*** prevent the elements b_2 and c_2 from becoming displaced upwards or downwards in relation to one another.

FIG. 13 shows a joint between adjacent elements formed with profile members in H shape indicated by reference numerals **19*a***, **21*a***, **119*a***, and **121*a***. The free ends of the profiles are formed with projections **22** having each an aperture of identical diameter and a common axis. In assembled position of the elements a pin **23** is inserted through said apertures and locks the projections of the adjacent elements profiles rigidly to one another. A seal of the joint may be obtained by means of a packing **24**. The pin may have its free end formed conically to render possible subjecting the elements to some prestress during the assembling operation.

FIG. 6 is an example of a joint between two adjacent elements consisting of a notch **25** formed in the abutting edge sides of said adjacent elements and in which is placed a strip **19*b***. The joint may be sealed by means of a packing **26** having the form of a ribbon or a T.

FIG. 7 is another view of the strip **19*b*** at its juncture with similar strips **119*b***, **21*b*** and **121*b***. At the point where the strips cross one another (see also FIG. 5) they are formed with apertures having identical diameter and a common axis. In the assembling operation a pin **28** is inserted through the apertures in all strips, and the joint is sealed by means of a packing **29**. The free end of the pin may be made conical which renders possible subjecting the elements to prestress.

FIG. 8 shows another embodiment of the locking of a strip-shaped seam. In the embodiment shown in FIG. 8 a washer **30** is provided with so many holes as there are strips such as **19*c***, **119*c***, **21*c*** and **121*c*** to be connected there. In the assembling operation wedged members **31** are inserted through the holes in the washer and corresponding holes in the strips which wedged members exert a tension on the strips and unite them together through the washer. Said washer may also have a threaded aperture to allow a threaded bolt **32** with a disc-shaped head to be threaded thereinto to seal the opening necessary for introduction of the wedged members **31**.

FIG. 9 illustrates a third example of a locking device for strips located in notches in the panel element edges. In the embodiment shown the strips **21*d*** and **121*d*** of adjacent elements are bent off at their opposite ends and joined together by means of a bolting **33**. The bolting joint may also be turned downwards as is indicated by dotted lines **34**. A disc **35** entering into grooves formed in both abutting elements may serve as a seal.

FIG. 10 shows an example of a U-shaped seam **19*e***. It is also possible to usc a tubular member. A U-shaped or a tubular seam may have a tension bar **36** running through its center.

FIG. 11 shows a locking means for nse in connection with a U-shaped or tubular seam **19*e***, **119*e***, **21*e*** and **121*e***. In the embodiment shown, the tension bar **36** is stretched by means of a device **37** bearing on the notch. A stretching member and tubular nut **38** may be used, said nut receiving also the free end of the tension bar **39** of the adjacent element.

The panels may be solid slabs of some suitable material such as glass, wood, synthetic plastic, or moldable materials such as concrete, porous concrete, foamed plastic, foamed glass, or the like. Panels may also be formed of several different materials. It may for example be composed of an uppermost moisturc-insulating layer made of cardboard, sheet metal and the like, thereunder a heat insulating layer consisting of, for example, wood wool, cork, porous concrete and like material, followed by a load sustaining layer made of concrete, for example, and lowermost a sound absorbing layer consisting of, for example, a fiber board provided on its free face with non-penetrating holes. Also on its lowermost flat side the element may be provided with a moisture impermeable sheet. The different matcrials are suitably bound together by cohesion produced by a moulding operation.

While several more or less specific embodiments of the invention have been shown and described, it is to be understood that this is for purpose of illustration only and that the invention is not to be limited thereby, but its scope is to be determined by the appended claims.

What I claim is:

1. A self-supporting roof for a building having the form of
   (a) a curved shell formed of a plurality of panel elements arranged to form a generally curved surface,
   (b) tension members associated with each panel element interconnecting several points spaced about each panel element,
   (c) means interconnecting the individual panel elements with the tension members for compressing the individual panel elements when the tension members surrounding the panel elements are connected and drawn together, and
   (d) means to place the said tension members under tension and to interconnect them with tension members of adjacent panels, whereby the tension members compressed the individual panel elements and join them together.

2. The structure of claim 1 in which
   (a) the panel elements are polygonal in shape and are arranged with their sides adjacent corresponding sides of adjacent panel elements, and
   (b) a tension member is located along each side of the polygonal panel elements and between the elements.

3. The structure of claim 1 in which the means to interconnect the tension members is a unitary structure engaging with three tension members, two of which are associated with different panel elements and one of which is common to two of the panel elements.

4. The structure of claim 1 in which the said coupling means include means for placing the tension members under gradually increasing tension.

5. The structure of claim 1 in which opposite ends of the tension members have apertures therein, and the coupling means includes a pin fitted in the apertures of a plurality of tension members meeting at a corner of a panel element.

6. The structure of claim 5 in which a portion of the pin is of wedge shape.

7. The structure of claim 1 in which the tension members are of H shape and the edges of panel elements fit between the flanges of the H-shaped tension members.

8. The structure of claim 1 in which the panel elements have notches in their lateral edges and the tension members are mounted within the said notches.

9. The structure of claim 1 in which the coupling means includes a threaded member.

10. The structure of claim 1 in which the tension mem-

bers comprise a rod member and a hollow member surrounding the rod.

11. The structure of claim 1 in which

(a) the curved shell comprises a dome like structure including a circular edge frame of angular shape defining the base of the dome, a plurality of triangular panel elements having their respective bases fitted within the angular portions of the circular edge frame and their apexes extending inwardly along the surface of the dome, a row of diamond shaped panel elements fitted in the dome surface by insertion of the angle of one diamond shaped element between each triangle element and other rows of diamond shaped panel elements arranged to form the dome surface with an apex of each diamond inserted between two other diamond elements of the preceding row,

(b) the tension members comprise beam members, each being positioned in the dome surface and adjacent the side of a diamond shaped element and being shaped to interengage with the panel element on each side of it, and

(c) the means to place the tension members under tension comprising apertures in the ends of each tension member overlapping apertures of tension members intersecting at the apexes of the diamond shaped elements, and pins having conical ends inserted within each set of overlapping apertures and positioned substantially perpendicular to the dome surface.

12. A self-supporting roof structure comprising

(a) a plurality of panel elements arranged to form a shell like surface,

(b) tension members running between points spaced about the periphery of each panel element,

(c) means interconnecting the individual panel elements with the tension members for compressing the individual panel elements when the tension members surrounding the panel elements are connected and drawn together, and

(d) means to couple the ends of the tension members to other tension members to

(1) place tension on the tension members,

(2) place the panel elements under compression, and

(3) interconnect the various panel elements to form a unitary roof structure.

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United States Patent [19]

Williams et al.

[11] **4,124,365**

[45] *** Nov. 7, 1978**

[54] **METHOD FOR MAKING CONTINUOUS FOAM GLASS PRODUCT**

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[*] Notice: The portion of the term of this patent subsequent to Jul. 26, 1994, has been disclaimed.

[21] Appl. No.: **794,283**

[22] Filed: **May 5, 1977**

Related U.S. Application Data

[62] Division of Ser. No. 641,810, Dec. 17, 1975, Pat. No. 4,038,063.

[51] **Int. Cl.**^{2} **C03B 19/08**

[52] **U.S. Cl.** .... **65/22**; 65/18; 65/88; 65/89; 106/40 V; 264/45.8; 264/122

[58] **Field of Search** .... 65/88, 89, 18, 22; 264/45.8, 122, 46.2, 56, 49, 110; 106/40 V

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4,038,063	7/1977	Williams et al.	65/89 X

Primary Examiner—Robert L. Lindsay, Jr.

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[57] **ABSTRACT**

A continuous process for the manufacture of cellular ceramic product. Ceramic feed material is transported successively through a preheat kiln section, through a foaming section whereat foaming agent mixed with the ceramic feed material is activated, and into a drawing kiln section. An elongate hollow product can be formed by drawing the foamed ceramic while soft around and past a hollow mandrel to form an elongate hollow cylindrical member.

4 Claims, 5 Drawing Figures

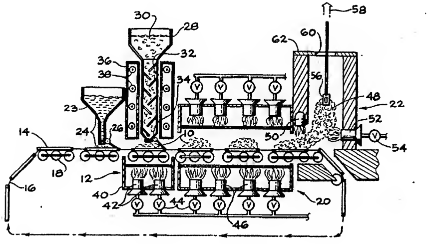
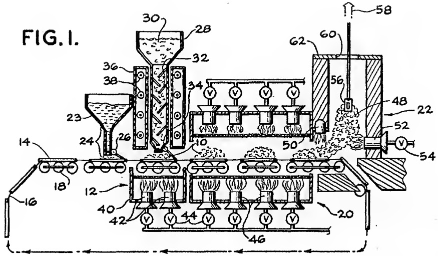


FIG. 1.



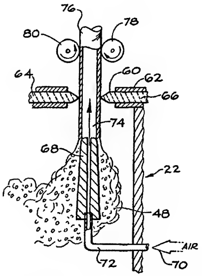


FIG. 2.

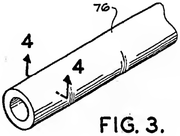


FIG. 3.

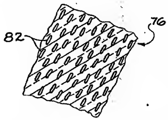


FIG. 4.

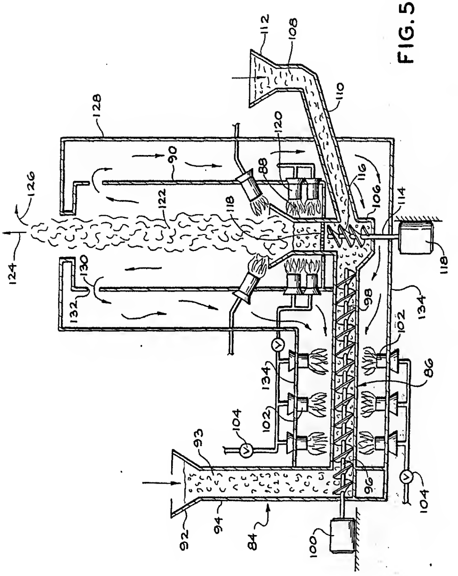


FIG. 5.

METHOD FOR MAKING CONTINUOUS FOAM GLASS PRODUCT

This is a division of application Ser. No. 641,810, filed 12/17/75, now U.S. Pat. No. 4,038,063, granted 7/26/77.

FIELD OF THE INVENTION

The present invention relates to the field of glass, more particularly the manufacture of foamed glass.

BACKGROUND AND SUMMARY OF THE INVENTION

An object of the present invention is to provide a process whereby a cellular ceramic product, which can be referred to simply as "foamed glass," is produced in a continuous and economical manner in the form of elongate members, more particularly in the form of hollow elongate cylinders. In such form, the foamed glass product can be used as a structural member in a number of industries including the housing industry as a bearing member, in processing industries as conduit, for example, as sewer pipe, and, in a particular exemplification, as a telephone pole or power line to replace wood poles. Particularly in the last utility, it will be appreciated that increasing demand for wood by numerous industries has caused shortages in the supply of wooden poles. Because of the inherent properties of the wood selected for such poles, they are excellent support members for high tension power lines and power poles have been constructed varying in length from 25 feet to almost 100 feet and formed to bear horizontal loads ranging in weight from below 400 lbs. to in excess of 11,000 lbs. However, material shortages and the competing demands for wood make it desirable to provide a substitute material. Such a material should be readily available, easily formed in lengths up to 100 feet, be able to withstand a stress of 5,000–8,000 psi, be economical in comparison with the purchase cost and life cycle cost of wood, be attractive or be capable of being made attractive, be fireproof and be a good electrical insulator.

The present invention provides such a material in the form of foamed glass produced by a continuous process which enables a pole structure to be directly obtained. In this general form, any glass composition can be used with appropriate foaming agents. In preferred embodiments, further economies are obtained by utilizing fly ash as a glass base or as a filler. Fly ash (calcium alumino-silicate, containing iron) is generated from coal and usually considered a waste material so that its utilization provides an extremely economical product.

More specifically, a continuous process is provided for the manufacture of cellular ceramic product in which a foaming agent is added to a ceramic feed, the foaming agent requiring a temperature in excess of 500° C. for activation. The process comprises transporting ceramic feed through a first kiln section and preheating it at a temperature of at least 500° C., but lower than the foaming agent activation temperature. Thereafter, the ceramic feed is transported into a second kiln section and a mixture thereof with the foaming agent is heated to the activation temperature for a time sufficient to form the foamed ceramic. The foamed ceramic is then transported while it is at or above its softening point to a drawing kiln section from which it is gathered and formed into product. The process is continuous so that while a first amount of the ceramic feed is fed through the kiln sections it is followed by a second amount either as a separate batch or continuously in a stream. In the first case, the ceramic feed mixture is initially deposited in powder form on refractory plates which are conveyed through the kiln sections, and the process can be referred to as a "power process." In the second case, the ceramic material and foaming agent are heated to melt together in a tank, and the process can be referred to as a "tank process." The powder process is particularly useful where it is desired to add the foaming agent directly to the ceramic feed whereas a tank process is particularly suitable for adding the foaming agent to the feed after preheating, i.e., after passage of the ceramic feed to the first kiln section. Additionally, as a result of thermal balances, the powder process is most suitable for the use of fly ash as a filler and a ceramic feed can be used containing about 1–30% by weight of fly ash. The tank process is particularly suitable for use of fly ash as the major component.

The product obtained is formed as an elongate member having a length of at least 10 feet and a width dimension of about 3–36 inches. Preferably, the elongate member is in hollow tubular form and is obtained by drawing the foamed ceramic, while soft, around and past a hollow mandrel while air is passed through the mandrel. Specifically, with a preheat temperature of about 500°–750° C. and an activation temperature of about 800°–1200° C., a foamed ceramic product is formed having a cellular structure of closed, elongate bubbles in which the bubbles have a diameter in the range of about 0.01 mm to about 1 cm and a length in the range of about 2 mm to about 5 cm, the volume of said bubbles constituting about 10% to about 90% of the volume of the foamed ceramic.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of apparatus utilized in a process conducted in accordance with one embodiment of the present invention wherein ceramic feed material is fed in batch form through tandemly arranged kilns;

FIG. 2 is a cross-sectional detail view of a portion of the apparatus of FIG. 1 illustrating the formation of a hollow elongate member;

FIG 3 is a perspective view of one end of a hollow elongate member formed in accordance with the present invention;

FIG. 4 is a cross-sectional view of a portion of the elongate member of FIG. 3, taken on line 4—4 of FIG. 3; and

FIG. 5 is a schematic representation of apparatus utilized in a process conducted in accordance with a second embodiment of the present invention.

DETAILED DESCRIPTION

As required, detailed illustrative embodiments of the invention are disclosed herein. However, it is to be understood that these embodiments merely exemplify the invention which may take forms that are different from the specific illustrative embodiments disclosed. Therefore, specific structural and functional details are not to be interpreted as necessarily limiting, but as a basis for the claims which define the scope of the invention.

Referring to FIG. 1, a continuous process is illustrated in which batches 10 of ceramic feed material are transported through a section of a preheat kiln 12. A plurality of flat refractory plates 14, e.g., of asbestos, are linked together by chain 16 and carried over rollers 18

in endless loop fashion through the preheat kiln 12 and through an adjacent, tandemly disposed foaming kiln 20 and from there into and out of a drawing kiln 22, returning back to the preheat kiln 12. Downstream of the preheat kiln 12, there is located a feed hopper 23 containing a release agent 24. The release agent can be carbon black, silicon fluid, or other such material as known to the glass art which will serve to prevent the ceramic feed from sticking to the refractory plates. Movement of the refractory plate past the release agent hopper 23 engages a linkage connected to a valve 26 on the hopper 23 resulting in deposition on the surface of the refractory plate of a quantity of the release agent 24. The refractory plate 14 then travels into the preheat kiln section 12 and past a hopper 28 containing ceramic feed material 30. The feed material 30 travels past baffles 32 and onto the refractory plate 14, also as a result of actuation by movement of the plate against linkage connected to a valve 34 located at the neck of the hopper 28.

The preheat kiln 12 includes a top preheat kiln 36 surrounding the neck of the ceramic feed hopper 28 and which is heated by means of burners 38 therein. Additionally, the preheat kiln 12 includes a bottom preheat kiln section 40, also heated by means of burners 42. The flames of the burners 38 and 42 play upon adjacent metallic wall panels so that the heat supply within the kiln is indirect. Of course, the rollers 18 are formed of refractory ceramic material so as to not be adversely affected by the heat generated by the burners 38 and 42. Appropriate valves 44 are provided for each burner so as to permit control of temperature as desired.

In the embodiment depicted in FIG. 1, the ceramic feed material 30 includes a foaming agent mixed therewith, and which will be described in more detail hereinafter. The temperature generated in the preheat kiln 12 is at least 500° C., but is below the temperature required for activation of the foaming agent. Generally, the preheat temperature is in the range of about 500°–750° C.

The preheated mixture of ceramic feed and foaming agent is transported into the foaming kiln section 20 which is heated by burners 46 to a temperature which is sufficiently high to activate the foaming agent, generally in the range of about 800°–1200° C. Activation of course, is not instantaneous but occurs over several seconds and the apparatus is designed so that as the ceramic feed material foams it it is transported into the drawing kiln section 22. At the drawing kiln section 22 the foamed ceramic 48 is further heated by the open flames of burners such as at 50 and 52, controlled by appropriate valves as at 54. As a result of the natural forces involved in formation of the foamed ceramic 48, it rises within the drawing kiln section 22.

During start-up operation of the process, the initial amount of foamed glass 48 is gathered by insertion into the product of a bait 56, as is known in the glassmaking art. The bait is pulled upwardly, as indicated by the arrow 58, through an opening 60 in the roof 62 of the drawing kiln 22 until it emerges from the opening. After the bait has drawn out an initial length of foamed ceramic product, the gather is thereafter transported by means of rollers or other mechanism (not shown) and the bait is simply broken away. The gather is continuously directed to a forming station to be formed into an elongate foamed ceramic product.

Referring to FIG. 2, details are illustrated of a particular forming process which can be used in conjunction with the apparatus of FIG. 1. In particular, a top section is shown in detail of the drawing kiln 22, roof 62 and opening therein 60. A pair of refractory, pointed formers 64 and 66 are located within the opening 60 spaced one from the other and centrally below which is disposed the terminal end of a conical, hollow mandrel 68. A stream of air, as indicated at 70, is fed through a conduit 72 through the hollow mandrel 68, exiting from the top thereof as indicated by the arrow 74. The initial gather of foamed glass 48 is directed by the bait around and past the outer surface of the hollow mandrel 68 and, as a result of the stream of air 70, forms into a hollow tubular member 76. The bait carries the initial product between a pair of rollers 78 and 80 spaced sufficiently distant from the drawing kiln so that the product drawn therebetween at that point is cooled enough to be rigid and substantially nondeformable. The bait is broken away above the rollers 78 and 80, which rollers are then rotated (by means not shown) to continue drawing the tubular product 76 from the drawing kiln 22 at a desired rate.

The rate of drawing is chosen so as to obtain a desired thickness of tube coordinated with the rate of movement of the ceramic feed material through the apparatus. The drawing rate can range from 1 inch per second to 1 inch per ten minutes and the viscosity of the foamed ceramic from the foaming kiln section to the exit of the drawing kiln is in the range of 1 poise–10,000 poises. The general physical properties of the resultant product will include a density in the range of 15–90 lbs./ft^3, a coefficient of thermal expansion of about 7 to 12 $\times 10^{-6}$/° C., zero flame spread under ASTM E84 and noncombustibility under ASTM E136.

Referring to FIGS. 3 and 4, the tubular product 76 formed as a result of the process is an elongate continuous member of foamed ceramic. As particularly shown in FIG. 4, the foamed ceramic has a cellular structure of closed elongate bubbles 82 having an elongate configuration and, as a result of the drawing process practiced herein, the majority of the bubbles are in substantial axial alignment. In other words, the longitudinal axis of most of the bubbles are extended in the direction of drawing of the tubular member. With the ceramic feed formulations and conditions hereinafter described, the bubbles have diameters substantially in the range of about 0.01 mm to about 1 cm and lengths substantially in the range of about 2 mm to about 5 cm, the volume of the bubbles constituting about 10% to about 90% of the volume of the elongate member 76.

Immediately following formation of the cellular ceramic tubular product, it is conveyed to an annealing lehr and maintained therein for a time sufficient to relieve strain. The amount of annealing depends, of course, on the composition of the glass mix and thickness of the product. Initially, the product is annealed at about 5° C. above its annealing point for a time ranging from about 5 minutes for ⅛ inch thick product to ½ hour for ½ inch product and longer, proportionately, for thicker products. The annealing point soda lime glass is about 545°–555° C.; for lead-alkali glass, about 430°–435° C.; and for borosilicate glass, about 495°–505° C. The specific annealing point for any particular glass composition can be approximated using tables of known annealing points for various compositions, all as known in the glassmaking art.

Thereafter, the product is cooled to just below its strain point over a period ranging from about 5 minutes to a period which is about ⅔ of the time the product is maintained above its annealing point. The strain point

for soda lime glass is about 505°-510° C.; for lead-alkali glass, about 390°-395° C.; and for borosilicate glass about 455°-520° C. Here too, the specific strain point can be approximated from known composition-strain point tables. Finally, the product is cooled to about 50° C. below the strain point over a somewhat shorter period and over a still shorter period to room temperature, all as generally known in the glass-making art.

Referring now to FIG. 5, an alternative embodiment is illustrated which can be referred to as a tank process and which includes a feed section **84**, a preheat kiln section **86**, a foaming kiln section **88**, which can also be referred to as the "tank," and a drawing kiln section **90**. In this embodiment, the sections are all connected together and the feed material is continuously moved by means of auger screw feeders. Additionally, the foaming agent is added to the ceramic feed after preheating of the ceramic feed.

Specifically, the feed section includes a hopper **92** into which is fed ceramic feed material **93** which travels down the elongate neck section **94** to the horizontally disposed preheat section **86**. Within the preheat section **86** there is located a screw feed **96** with auger flights **98** driven by a motor **100** and pitched so as to drive the ceramic material through the preheat section **86** toward and into the foaming section **88**. The preheat kiln section **86** is heated by burners **102**, controlled by valves, such as at **104**, so that the material within the preheat section is heated to about 500°-750° C.

The terminal end of the preheat kiln section **86** opens into a mixing chamber **106**. Foaming agent **108** is delivered into the mixing chamber **106** by means of a chute **110** connected thereto and fed from a hopper **112**. A screw feed is located within the mixing chamber **114** and has its auger flights **116** rotated by a motor **118** so as to direct the ceramic feed **93** and foaming agent **107**, as a mixture, through a perforated refractory plate **118** (e.g., of asbestos) into the foaming kiln, or tank, section **88**. At that section, additional burners **120** heat the mixture past the activation temperature of the foaming agent, to a temperature of 800°C.-1200° C., causing the mixture to foam whereupon it rises as foamed glass **122** into the drawing kiln **98**. As with the process depicted in FIG. 1, initially a bait is lowered into the drawing kiln to gather the foamed glass and it is thereby drawn out of the drawing kiln **90** and directed upwardly as indicated by the arrow **124**, or horizontally as indicated by arrow **126**, to a product forming station. The product can be formed into a hollow elongate member as depicted in FIGS. 3 and 4 by means of ancillary apparatus as shown in FIG. 2. In the particular embodiment illustrated in FIG. 5, the drawing kiln **90** is surrounded by a shell **128** spaced therefrom. Hot air **130** from the drawing kiln **90** escapes through openings **132** into the space between the shell **128** and the drawing kiln **90**, and is directed back to the burner section below and above the preheat kiln section **86** enclosed by horizontal extension walls **134** of the shell **128**. The process is made more efficient by such utilization of the hot air returned from the drawing kiln.

In the most general form of the invention, any ceramic feed material can be used which will form a glass composition, including glass itself. Of course, silicates (SiO_2) such as is the predominate component of sand, is the major constituent of most commercial glasses and constitutes a fundamental material in the present ceramic feed. Additionally, soda (Na_2O) and lime (CaO) can be used as common ingredients as can potash (K_2O), lead oxide (PbO), magnesium oxide (MgO), aluminum oxide (Al_2O_3), boron trioxide (B_2O_3), and the like. Additionally, oxidizing or reducing agents, or decolorizing or coloring agents can be added, as can opacifying or nucleating agents, as well as excess glass from a previous melt such as cullet as generally known in the glass-making art.

In addition to the usual oxides found in ordinary glass, the present invention is found to be particularly suitable for the incorporation of fly ash. Fly ash is usually an iron bearing calcium alumino-silicate generated from coal and is usually considered as waste material. In conducting the powder process as described with respect to FIG. 1, one can add from 1 to 30% fly ash as filler, thus diluting the ceramic with an inexpensive material yet which provides a product having all the desired properties. In conducting the tank process as described with respect to FIG. 5, one can use substantially more fly ash and in fact one prefers to use at least 50 weight percent fly ash and can conduct the process entirely with fly ash. Accordingly, one can use from 50% to 100% fly ash, the remainder, if any, to be constituted of the usual glass forming oxides.

As foaming agent, one can use any material that is usually used in foaming glass. Accordingly, one can use inorganic carbonates such as sodium carbonate, lithium carbonate, potassium carbonate, dolomite, or inorganic sulfates such as sodium sulfate, potassium sulfate and the like or one can simply use carbon such as carbon black or the like. The amount of foaming agent used can be in the range of about 0.5-20% of the weight of the ceramic-forming materials, but lower or higher amounts can be used for specific effects.

The following examples, in which all parts and percentages are by weight, will further illustrate the invention.

EXAMPLE 1

A process can be conducted utilizing the apparatus depicted in FIGS. 1 and 2 to obtain an elongate pole structure of foamed ceramic having the physical characteristics hereinbefore described. As a ceramic feed, one can use a mixture of 2% fly ash and 98.0% other glass-forming oxides. As the other glass-forming oxides one can use a mixture comprising 73.0% SiO_2, 13.5% Na_2O, 9.0% CaO, 3.0% MgO and 1.5% Al_2O_3. As the fly ash one can use Ohio fly ash comprising 52.1% SiO_2, 32.0% Al_2O_3, 3.3% Fe_2O_3 and 12.6% impurities. As foaming agent one can use calcium carbonate, in an amount equal to 10% of the weight of the glass-forming oxides and fly ash, mixed in therewith.

Carbon black can be placed on the refractory plates, as a release agent. The preheat kiln section can be heated so that the ceramic feed material attains a temperature therein of 650° C., with a maximum of 750° C. The foaming kiln section can be heated so that the ceramic feed mixture attains a temperature therein of 950° C. The gather can be drawn at a pull rate of about ½ inch/second and with a viscosity at the drawing point of about 5000 poises. A tubular cellular ceramic product can thus be obtained having 50% porosity where the bubbles constituting the pores have an average diameter of 1 mm and an average length of 4 mm. The product has a thickness of ½ inch and is annealed at 553° C. for about 60 minutes followed by a reduction in temperature to about 500° C. over about 40 minutes, and then to about 450° C. over a period of about 25 minutes, to room temperature over about 20 minutes. A product is

obtained having the general physical properties as hereinbefore described.

EXAMPLE 2

The process described in Example 1 can be repeated, but using a ceramic feed mixture in which 10.0 weight percent fly ash is mixed with other glass-forming oxides. The other glass-forming oxides can comprise 73.6% SiO_2, 16.0% Na_2O, 0.6% KaO, 5.2% CaO, 3.6% MgO and 1.0% Al_2O_3. As the fly ash one can use material comprising 32.0% SiO_2, 20.8% Al_2O_3, 34.9% Fe_2O_3 and 12.3% impurities. The foaming agent can be sodium carbonate at a level of 5%. The product can be annealed using the schedule in Example 1, but at 515° C., followed by a reduction in temperature to 465° C., then to 415° C. and, finally, to room temperature. A product can thus be obtained having the general physical properties as hereinbefore described.

EXAMPLE 3

The process described in Example 1 can be repeated but one can mix 21.0 weight percent fly ash with other glass-forming oxides. As such other glass-forming oxides, one can use a mixture comprising 63.0% SiO_2, 7.6% Na_2O, 7.0% K_2O, 0.3% CaO, 0.3% MgO, 0.2% B_2O_3, 0.6% Al_2O_3 and 21.0% PbO. As fly ash, one can use material comprising 50.1% SiO_2, 33.2% Al_2O_3, 10.7% Fe_2O_3 and 6.0% impurities. The foaming agent can be potassium sodium sulfate at a level of 18%. The product can be annealed using the schedule in Example 1, but at 440° C., followed by a reduction in temperature to 390° C., then to 340° C., and, finally, to room temperature. A product can thus be obtained having the general physical properties as hereinbefore described.

EXAMPLE 4

A process can be conducted utilizing the apparatus depicted in FIGS. 5 and 2 to obtain an elongate pole structure of foamed ceramic having the physical characteristics hereinbefore described. As a ceramic feed material added to the preheat kiln section, one can use a mixture of 55.0% fly ash and 45.0% of other glass-forming oxides. As the other glass-forming oxides, one can use a mixture comprising 75.0% SiO_2, 10.1% Na_2O, 1.3% K_2O, 7.3% CaO, 4.8% MgO and 1.5% Al_2O_3. As the fly ash, one can use Ohio fly ash comprising 40.3% SiO_2, 21.5% Al_2O_3, 27.5% Fe_2O_3 and 10.7% impurities. As foaming agent added separately, following preheat, as above described, one can use calcium carbonate at the rate of 10% of the ceramic feed mixture.

The preheat kiln section can be heated so that the ceramic feed material attains a temperature therein of 700° C. with, a maximum of 750° C. The foaming kiln section can be heated so that the mixture of foaming agent and ceramic feed mixture attains a temperature therein of 1000° C. The gather can be drawn at a pull rate of about 1 inch per second and with a viscosity at

the drawing point of about 1000 poises. The product has a thickness of ½ inch and can be annealed using the schedule in Example 1. A tubular cellular ceramic product can thus be obtained having 50% porosity wherein the bubbles constituting the pores have an average diameter of 1 mm and an average length of 4 mm, the product having the general physical properties as hereinbefore described.

EXAMPLE 5

The process of Example 4 can be conducted but one can use a ceramic feed mixture containing 75% fly ash. The other glass-forming oxides can be formed from a mixture containing 80.5% SiO_2, 4.0% Na_2O, 0.4% K_2O, 12.9% B_2O_3 and 2.2% Al_2O_3. The fly ash component can comprise 45.7% SiO_2, 29.8% Al_2O_3, 17.9% Fe_2O_3 and 6.6% impurities. The foaming agent can be lithium carbonate at a level of 2.0%. The product can be annealed following the schedule of Example 1. A tubular cellular product can thus be obtained having the general physical properties hereinbefore described.

EXAMPLE 6

The process of Example 4 can be repeated but using 100% fly ash having the following composition: 44.6% SiO_2, 35.4% Al_2O_3, 12.4% Fe_2O_3 and 7.6% impurities. The foaming agent can be dolomite at a level of 15%. The product can be annealed following the schedule of Example 1. A tubular cellular product is thus obtainable having the general physical properties hereinbefore described.

We claim:

1. A moldless process for the manufacture of cellular ceramic product in which a foaming agent is added to a ceramic feed, said foaming agent requiring a temperature in excess of 500° C. for activation, comprising:
   heating said ceramic feed to a temperature of at least 500° C. but which is lower than said activation temperature;
   thereafter, adding foaming agent to said heated ceramic feed to form a mixture thereof;
   heating said mixture of foaming agent and heated ceramic feed to said activation temperature for a time sufficient to form foamed ceramic therefrom; and
   drawing said foamed ceramic to form said product.

2. The process of claim 1 wherein said first temperature is in the range of about 500° C. to 750° C. and said activation temperature is in the range of about 800° C. to 1200° C.

3. The process of claim 2 wherein said ceramic feed comprises a major amount by weight of fly ash.

4. The process of claim 3 in which said product is formed by drawing said foamed ceramic while soft, around and past a hollow mandrel while air is passed through said mandrel.

* * * * *

Oct. 2, 1962 E. BLAHA 3,056,184

MANUFACTURE OF UNIFORM CELLULAR CERAMIC ARTICLES

Filed July 23, 1959

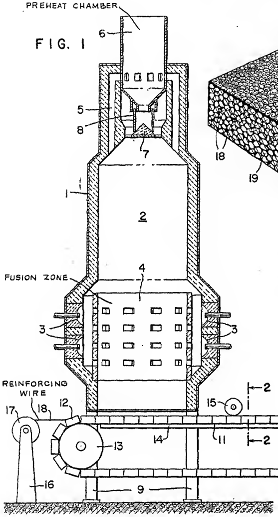


FIG. 1

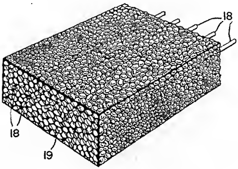


FIG. 3

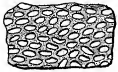


FIG. 4

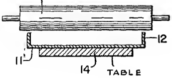


FIG. 2

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3,056,184

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3,056,184
MANUFACTURE OF UNIFORM CELLULAR CERAMIC ARTICLES

Emil Blaha, Cheltenham, Pa., assignor to Selas Corporation of America, Dresher, Pa., a corporation of Pennsylvania

Filed July 23, 1959, Ser. No. 828,966
5 Claims. (Cl. 25—156)

The present invention relates to a cellular ceramic product that is useful as a structural load supporting material and the method by means of which the material can be made. This application is a continuation-in-part of my application Serial Number 769,279 filed October 24, 1958, now abandoned.

There is a definite need in the building industry for a structural material that can be formed as a panel of various thicknesses and densities and is inexpensive to manufacture. The material of the present invention has these desirable characteristics, and, in addition, is non-absorbent to moisture so that it may be used as an outside wall.

It is an object of the invention to provide a cellular ceramic material that can be used for structural or other purposes and can be formed as a panel of various thicknesses and densities. It is a further object of the invention to provide a panel of cellular material that is sufficiently strong to be used for structural purposes.

In practicing the invention, material of selected composition is formed into small particles of a uniform size. These particles are dropped through a zone at a temperature sufficiently high to fuse and bloat them into individual hollow spheres of unicellular or multicellular form. These spheres are collected while their surface is still tacky. As the spheres cool they will fuse together to form a slab of cellular material that is completely impervious to moisture and has sufficient strength to be used for structural purposes.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

In the drawings:

FIG. 1 is a diagrammatic view of a particle bloating furnace,

FIG. 2 is a view taken on line 2—2 of FIG. 1,

FIG. 3 is a view of the material produced, and

FIG. 4 is an enlarged view of the surface of the material.

Apparatus with which the material can be prepared will first be described. This will preferably include a tower furnace like that shown in my copending application Serial Number 652,027 filed April 10, 1957, now abandoned. Such a furnace is shown diagrammatically in the drawing. Referring to FIG. 1, there is shown a tower furnace 1 that includes a vertically extending cylindrical furnace chamber 2 which is provided around its lower portion with a plurality of radiant cup type burners 3 that are located behind a refractory checkerwork 4. The burners are supplied with a combustible mixture of gas and air and produce radiant heat that is directed toward the checkerwork and the center of the furnace chamber. The checkerwork serves to break up any forward movement of the combustion gases and becomes incandescent to direct radiant heat across the furnace chamber. The hot products of combustion rise in the furnace chamber with a minimum of turbulence to pass through a series of ducts 5 that discharge into a preheat chamber 6 located above the furnace chamber. Between the preheat chamber and the top of the furnace chamber is apparatus for controlling the flow of particles between them. This apparatus includes a conically shaped stopper 7 that is supported concentric with chamber 2 at its upper end. A sleeve 8 of a diameter smaller than the base of stopper 7 rests on this stopper with its upper end receiving particles from chamber 6. When the sleeve engages the stopper, the flow of particles into the furnace is stopped. When the sleeve is raised an annular stream of particles flows around the stopper and drops vertically through the relatively quiet atmosphere of chamber 2. The particles fall in a straight path without engaging the side walls of the chamber.

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The furnace is mounted with its open, lower end elevated above floor level by supports 9 so that a collecting apparatus may be located under it. The collection apparatus includes a conveyor belt 11 of a width equal to the diameter of the furnace and moving below its open end. The belt may be used to carry molds, but is shown herein as being provided with sides 12 so that it forms a channel in which the bloated particles are collected. The belt moves over guide rollers 13, one of which serves as a drive and may be driven at a desired speed by a conventional variable speed motor. The upper reach of the conveyor is supported by a table 14.

At times it may be desirable to compact the material as it is collected. This can be accomplished by a roller 15 that is positioned above the conveyor belt adjacent to the furnace. At times it may also be desirable to reinforce the material as it is being made. To this end there is provided a stand 16 beyond the end of the conveyor which supports a reel 17 of reinforcing material. As shown herein, the reinforcing material comprises a plurality of wires 18 that are side by side and extend along the belt between sides 12. It will be apparent that a wire mesh fabric could be used instead of wires if it was so desired.

In practicing the invention, the raw material used can be of any desired composition as long as it has the characteristic of bloating when heated to its fusion temperature. The bloating occurs as a result of the release of CO_2 or other gases from the material during heating. Such materials include any of the natural clays and many mixtures of materials that form essentially a glass batch. A specific mixture that is essentially a glass batch which will produce a strong, rigid product may be:

Silica	8–25% by weight.
Lime and/or magnesia	12–25% by weight.
Alumina	balance.

The raw batch incorporates the lime and magnesia at least partially as carbonates. This material has a melting range of from 2100 F. to 2800 F.

In preparing the material, the clay, or, if a glass, the thoroughly mixed ingredients of a batch, are moistened sufficiently so that they will assume the consistency of a plastic mass. This mass is then broken up into small particles of a uniform size of about $\frac{1}{16}$ to $\frac{1}{8}$ inch long and about $\frac{1}{32}$ inch in diameter. The particles are dried and are then in condition to be fused. Thus the starting material is formed into discrete particles of substantially the same size, and the particles are substantially dust free.

The particles are placed in preheat chamber 6 in sufficient quantities to keep the sleeve 8 filled at all times while the furnace is in operation. Hot products of combustion from the furnace chamber passing through ducts 5 into chamber 6 will preheat the particles to a temperature slightly below the point where their surfaces will become tacky.

When sleeve 8 is raised an annular stream or column

of particles will fall through furnace chamber 2. By the time the particles pass in front of checkerwork 4 they will have been heated predominately by radiant heat to above their fusion temperature which will range from about 2100 F. to 2800 F. depending upon the composition of the starting material. As this take place, the gas generated in the particles causes them to expand or bloat into hollow spheres. The size of the spheres will be determined somewhat by the time they are above fusion temperature with the spheres growing with increased time. Since, however, the particles are originally substantially the same size and they will take the same time to fall through the furnace, the spheres will also be substantially the same size.

The spheres fall on belt 11 or a mold carried thereby and will be collected to a thickness depending upon the speed of the belt. As the surface of the spheres is still tacky when they land on the belt they will stick or fuse to each other to form a slab of cellular, agglomerated material. The initial batch used whether a clay or a form of glass will produce individual spheres and a slab, having a glazed or glasslike surface. The material, being made of individual cells, is non-porous and will not absorb water.

Ordinarily the slabs produced will have a density of from 18 to 35 pounds per cubic foot, depending upon the raw material. A slab of a density of 42 pounds per cubic foot will have a compressive strength in excess of 1200 pounds per square inch. The density of the slab can be increased by compressing it and forcing the individual spheres closer together. This can be accomplished, if desired, by moving the slab under roller 15 that is located close enough to the point of collection so the material has not cooled to a point where it is rigid. The density of the slab is varied by varying the amount it is compressed. If the slab is to be reinforced, wires 18 are threaded along the belt. The spheres will then build up around the wires so that they are completely embedded therein.

The lower surface of the slab will be smooth as determined by the surface of the belt. The upper surface will be glazed and will have an interesting pebbled pattern created by the spheres. The surface, however, is continuous. After the slab is formed it can be cut by ordinary masonry cutting tools to any desired shape and size. The cut surface will have, as shown at 19 in the drawing, a multiplicity of holes formed by the spheres that were cut. Since the interior of the spheres is also glazed and the pores or cells are discontinuous, a cut surface is as water proof as the original. In some cases it may be desirable to sprinkle a granular material such as sand on the belt before the spheres are collected. When this is done they will stick to the sand to produce a rough surface to which plaster, for example, will adhere.

The method of making the slab by collecting the spheres one on top of the other insures that the slab produced will have a uniform cellular structure throughout its thickness. After the slab has been formed it can be annealed, if necessary, to remove any internal strains that it may have. Thus there is produced a strong, rigid slab of material that has a uniform cellular structure. This material, because of its inherent characteristics is ideally suited for structural panels to be used in both the interior and exterior of buildings.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit and scope of the invention set forth in the appended claims, and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

What is claimed is:

1. The method of forming an agglomerated structural material which comprises dropping individual particles of a mixture capable of forming a vitreous material and having the characteristic of bloating and becoming tacky on its surface when heated, vertically downward under the force of gravity through a fusion zone, heating said particles above their fusion temperature as they pass through said zone whereby said particles are bloated into individual hollow bodies, collecting the bodies in a mass while their surfaces are still tacky whereby the bodies will stick together to form a body of cellular agglomerated material, and cooling said material to form a body of rigid material.

2. The method of claim 1 including collecting said bodies on a moving surface, moving said surface past a point of collection below said fusion zone at a rate so that the bodies collected thereon will build up to a desired thickness.

3. The method of claim 2 including compressing the material collected on said moving surface to increase its density prior to the time it has cooled enough to become rigid.

4. The method of claim 2 including placing reinforcing material above said moving surface and collecting the bodies around said reinforcing material.

5. The method of making a cellular structural material which comprises, dropping a bloatable material in the form of a multiplicity of small particles of substantially the same size of a mixture capable of forming a vitreous material and of becoming tacky on its surface when heated vertically downward under the force of gravity through a fusion zone, rapidly heating said particles to fusion temperature as they fall through said zone whereby they will be individually bloated to spherical form, collecting said particles below said fusion zone while their surfaces are still tacky as a mass of cellular material, gradually moving said mass from the collection point to form a slab, and cooling said mass so that it will become rigid.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,056,184 October 2, 1962

Emil Blaha

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, lines 49 to 51, strike out

Silica-------------------------------	8-25% by weight.
Lime and/or magnesia----------------	12-25% by weight.
Alumina------------------------------	balance.

and insert instead

Lime and/or magnesia---------------	8-25% by weight.
Alumina----------------------------	12-25% by weight.
Silica-----------------------------	balance.

Signed and sealed this 5th day of February 1963.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

United States Patent Office

3,459,565

Patented Aug. 5, 1969

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FOAMABLE GRANULE PRODUCT WITH METHOD OF PREPARATION AND MOLDING

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No Drawing. Continuation-in-part of applications Ser. No. 204,048, June 19, 1962, Ser. No. 510,418, Oct. 1, 1965, and Ser. No. 523,528, Jan. 28, 1966. This application Mar. 13, 1967, Ser. No. 622,459

Int. Cl. C03b *19/08;* C03c *3/04*

U.S. Cl. 106—40 8 Claims

ABSTRACT OF THE DISCLOSURE

A method of preparing an unfoamed, foamable glass mass containing undissolved, entrapped, compressed gas which comprises melting a glass mass under at least 100 p.s.i. pressure of an inert gas, and maintaining said pressure during cooling until said mass has solidified.

This application is a continuation-in-part of copending applications Ser. No. 523,528, now abandoned, filed Jan. 28, 1966, and Ser. No. 510,418, now abandoned, filed Oct. 1, 1965. Parent application Ser. No. 523,528, is in turn a continuation-in-part of Ser. No. 204,048 now abandoned, filed June 19, 1962.

It is an object of the present invention to provide a novel solid essentially unfoamed foamable granule which is substantially non-friable, vitreous, may be readily handled and shipped, and which is infinitely storable.

Another object of the invention is to provide a novel method of synthetically preparing a solid unfoamed foamable granule.

A further object of the invention is to provide a method of molding foamable granules as defined herein in a mold to provide a shaped molded foamed inorganic article of low density and uniform small cell size.

In accordance with the present invention, solid unfoamed foamable granules are prepared by (1) heating a comminuted inorganic glass-forming material mixture having a silicon dioxide content of at least about 50 weight percent under a gas pressure of at least about 100 p.s.i. at a temperature sufficient to melt the inorganic glass-forming mixture into a vitreous mass and entrap compressed interstitial gas, and (2) cooling the vitreous mass to a temperature sufficient to solidify the same while maintaining such mass under a pressure of at least about 100 p.s.i., thereby to produce a solid glass-like unfoamed foamable product which, as an optional additional step in the process, may be ground to suitably sized foamable granules of, e.g. from about 1/20" to about 1", preferably 1/8" to 1/2".

As a unique product, the solid unfoamed foamable pressurized granules of the present invention are characterized as an essentially unfoamed glass-like solid which may be foamed upon subsequent heating, the solid granule having a density approaching that of vitreous glass. For example, solid unfoamed granules made in accordance with the present invention employing about 1000 p.s.i. pressure both during the heating and cooling operations have a density of about 2.035 grams per cubic centimeter, or about 90 percent that of the vitreous silica (2.295 gm./cc. density). In any event these unique unfoamed, foamable glass-like masses or granules are normally characterized by a density of at least about 2.0 grams per cubic centimeter. In appearance these granules essentially resemble poorly fined glass particles and upon microscopic examination are somewhat more opaque than ordinary glass. These synthetic unfoamed foamable granules have the advantage of being essentially

non-friable, indefinitely storable, and shippable without damage or hazard. A potential user may order such granules in bulk, and use as necessary without fear of damage and the like. Moreover, large voluminous storage areas are not required, as would be in storing a foamed material.

The term "glass-forming materials" as used herein refers to a composition which contains at least about 50 weight percent silicon dioxide, the balance being composed essentially of one or more other glassforming substances. The chemical composition of the glass is given in terms of boric oxide, phosphorous pentoxide, germanium oxide and the like, and/or minor amounts of one or more glass modifiers such as potassium oxide, sodium oxide, calcium oxide, magnesium oxide, and the like. These compositions are produced by using such chemicals as borax, calcium phosphate, sodium or potassium or calcium carbonate and magnesium oxide. The glass-forming materials used herein as defined may either be in crystalline or in vitreous form.

Any comminuted inorganic glass-forming material which contains at least about 50 percent silicon dioxide is applicable as a starting material in making the synthetic solid unfoamed foamable material of the present invention. When the silicon dioxide content is below the indicated level, the resultant foamed product is generally at least partially soluble in water and less stable to chemicals and thermal shock.

It is often advantageous to subject foamed articles produced from the foamable material of the present invention, containing less than about 99 weight percent silicon dioxide, to temperatures sufficient to anneal the same following formation thereof to obtain maximum strength properties. It is normally unnecessary to anneal foamed articles produced from foamable glass containing at least about 99 weight percent silicon dioxide.

Examples of typical commercial inorganic glassforming materials that may be employed in the practice of the invention to make the present novel solid unfoamed foamable mass or granule are shown in the following Table I. Vitreous silica which is non-crystalline, e.i. ground fused quartz, can also readily be employed in the invention.

TABLE I

	A	B	C	D	E
SiO_2	99	96	80	51	60.2
Al_2O_3	0.07		2		3.8
CaO	0.04		.06	14	0.8
MgO	0.0005			3.4	
Fe_2O_3	0.03			9.7	
B_2O_3		3	14		25.8
Na_2O			3.56		7.8
K_2O	0.013		0.38		1.6
TiO_2	0.008				
PbO_2	0.002				
Soft. p.	[1] 1,650	1,500	819		

[1] After fusion.

Generally, it is preferable in the practice of the invention, that the comminuted inorganic glass-forming material be of a very fine texture, approaching that of a powder. Beneficially, the glass-forming material should be sized to pass at least a 50 mesh screen, and preferably a screen between 200 and 325 mesh. Larger sized particles may be used but lower expansion and larger cells may result in the resultant foam.

The temperature that must be used in heating the comminuted inorganic glass-forming material is that which is at least the softening point of the material. Generally, it is preferred to heat such materials using the lowest possible temperatures to minimize migration of any compressed gas within the heated mass.

Temperatures between about 600° C. and 1800° C. are generally sufficient to melt the materials described

herein, depending for the most part upon the silicon dioxide content of the material. It is generally preferred to melt materials composed essentially of silicon dioxide, that is, materials having a silicon dioxide content of about 99 weight percent at temperatures of about 1650° C. to 1750° C.

The temperature required to melt the comminuted inorganic glass-forming material may be lowered by intimately admixing with the glass-forming material prior to melting of the same, of small amounts of glass-modifiers which do not induce excessive divitrification. Representative of such glass-modifiers are boric oxide and certain coloring agents such as cobalt oxide.

In order to obtain the uniform, small, closed cell foam upon subsequently heating the solid unfoamed foamable granules made in accordance with the invention, the inorganic glass-forming material must of necessity be pressurized with a suitable gas prior to being melted. Ordinarily, a gas pressure of at least 100 p.s.i. is employed, and preferably, between about 200 p.s.i. and 800 p.s.i. is utilized for superior uniformness of cell structure through the resultant foam. Because of the reactivity of many gases with the materials of construction in the furnace or enclosed chamber in which the material is fused, inert gases such as nitrogen and argon are preferably employed. However, many other gases such as carbon dioxide, ammonia, and suitable mixtures thereof, among others may be employed.

It is to be noted that many of such gases are known to be somewhat soluble in the glass-forming materials described herein. Thus, in the practice of the present invention, the cooled, pressurized solid unfoamed vitreous mass will contain dissolved gases in addition to compressed undissolved gases. It is not possible, however, to introduce an adequate amount of gas into the mass after melting. In any event the solid unfoamed foamable material should contain sufficient gas or gases to expand such material at least about two and preferably five volumes upon subsequently heating same to elevated temperatures, e.g. in a mold, at normal atmospheric pressures.

It is also to be noted that cellulation of the final foamed product may be somewhat enhanced by intimately admixing with the comminuted inorganic glass-forming material prior to melting, small amounts of a conventional gas generating substance. However, such cellulating agents are not essential in the present invention.

Carbon black is an example of such a gas generating substance and may be employed in a range of, for example, 0.01 to 0.5 weight percent and preferably between 0.05 and 0.2 weight percent based on the weight of the glass-forming material, dependent upon the degree of cellulation desired. It, too, should be in very finely pulverized or pigmentary form, for example, wherein at least 95 percent of the charge may be passed through a 325 mesh screen. Other finely pulverized carbon or carbonaceous material such as powdered coal may also be mixed with the solid comminuted inorganic glass-forming mixture of the present invention in amounts of between 0.01 and 0.5 percent by weight, dependent somewhat upon the degree of cellulation desired and the material employed.

Other commonly used gas-generating substances found to be suitable for the purposes of the present invention include, but are not restricted to, inorganic carbonates, i.e. magnesium carbonate; silicon monoxide, metals, i.e. silicon metal, silicic acid, magnesium nitride, and suitable mixtures thereof. Typically about 5 weight percent of substances of these types would be added.

In a preferred embodiment of the method of the present invention for preparing synthetic solid unfoamed foamable granules, a comminuted inorganic glass-forming quartz material in a mesh size of from about −200 to about +325 mesh, having a composition as set forth in Example I, is enclosed in a chamber or mold cavity and pressurized by a gas such as nitrogen or argon either in or about the mold cavity preferably to at least about 200 p.s.i. to form a pressurized vitreous mass, and cooling the mass under at least 200 p.s.i. of pressure to solidify same, and optionally granulating the cooled mass to produce synthetic solid unfoamed but foamable granules. In general, the operating conditions of the method of the present invention for making granules should be adjusted sufficient to cause expansion of the granules when subsequently reheated and foamed at least about two volumes and preferably five volumes, at normal atmospheric pressure.

Synthetically prepared foamable granules, such as the novel solid unfoamed foamable granules prepared by the method of the present invention, and other synthetic foamable granules not necessarily prepared in accordance with the present invention, which may be stored until needed then foamed and cast in a mold to successfully make low density, shaped, foamed articles conforming in dimension closely to a mold cavity, have heretofore been unknown.

These synthetically prepared, foamable granules, including the solid unfoamed pressurized, foamable granules of the present invention may be heat foamed or expanded and molded in a closed mold to form a foamed glass article of predetermined density. In this process heat foamable granules are introduced into a closed cavity of a mold and the mold and contents heated to effect foaming. The foamed mass is cooled at least to a point where its structure is essentially rigid enough to be self-supporting whereupon it may be removed from the mold, annealed in an oven and/or further cooled to room temperature. The amount of foamable granules to be introduced into the mold may be predetermined and are dependent primarily upon the desired density of the foam. The size of the granules should be small with respect to the smallest interstices of the mold and preferably at least as fine as ⅛ to ½ inch.

When a borosilicate foam is prepared, carbonates such as sodium and potassium carbonate, are desirable additives, giving low density moldings (below 10 lbs. ft.$^{-3}$). The carbonates are added at about 5% by weight. When carbon or silicon is used as an auxiliary blowing agent the amount is kept much smaller (less than 0.5%) in order to get a white foam. Pressurization is preferably conducted, e.g. at 1200° C. and molding is preferably done at 775–825° C.

The temperature that must be used to cause the solid pressurized vitreous mass to expand is that which is at least the softening point of the mass. Generally, temperatures ranging from about 60 centigrade degrees above the annealing point of the mass (A.S.T.M. designation C 336) to about 300° C. above the softening point of the mass (A.S.T.M. designation C 338) are employed. These temperatures generally provide a mass having a viscosity between 10^5 and 10^{12} poises. The preferable viscosity range being between about 10^6 and $10^{7.5}$ poises. Generally, foaming temperatures between about 600° C. and 1800° C. are employed.

Although the solid, glass-like, unfoamed, foamable, pressurized glass granules produced by the method of the present invention are very satisfactory for carrying out the molding process, it is to be understood that any of a variety of heat foamable glass granules can be molded in accordance with the presently disclosed molding process. For example, in addition to the solid unfoamed foamable granules prepared by the process disclosed herein, molded foamed articles can be fabricated using synthetic glass compacted granules produced in the following manner: A particulated glass mixture is provided comprising (1) a pulverised glass containing at least about 50 weight percent of SiO_2 whose softening point is between about 700° C. and about 1800° C., (2) one or more gasing agents capable of producing gases over the foaming temperature range where the molten glass mixture has a viscosity of e.g. from about $10^{5.6}$ to about $10^{8.1}$ poises, and (3) a water soluble binder material which preferably becomes a component of the glass during the molding

and foaming operation, is provided in particle size the particles of which preferably do not exceed 50 mesh U.S. Standard Sieve and preferably contain particles at least 50% of which are as fine or finer than 400 mesh. This glass mixture is admixed with a liquid such as water, compacted, e.g. in an inclined pan granulator, and dried into foamable compacts of pellets or balls having a size preferably of from about ⅛ to 1 inch in cross-section, said pellets having an apparent density of at least 50% of the absolute density of the glass mixture being employed. The resulting pellets are used in the novel molding process described directly hereinbefore.

Foams obtained from these compacted materials are characterized by cells of size less than 3 mm. but normally not as fine as those obtained with the previously described pressurized glass granules.

Thus, a highly advantageous and beneficial foamed glass may be produced having excellent and superior properties, particularly in regard to the manufacture of articles such as structural materials requiring strength, resistance to weathering, impermeability to water and other liquids and having smooth easily cleaned finished facings.

Still another advantageous characteristic of foamed glass derived from the present invention is the essential absence of a gray or black color commonly observed in conventionally prepared foams since cellulating agents are not required. Thus, various coloring agents may be incorporated in the comminuted inorganic glass-forming materials to form foamable granules for producing brightly colored expanded molded articles. If carbon is used, however, it can be used so efficiently as to be consumed leaving no black residue.

As purely exemplary of foamed articles derived from the present invention are: structural blocks, planks, panels and the like for exterior use, insulating board, and expanded vitreous pellets and articles made by fusing together such expanded vitreous pellets. Such articles are characterized by having a cell size less than 1 millimeter and generally less than 0.3 millimeter, at least 80 percent closed cells and often 100 percent closed cells, and a density of less than about 60 pounds per cubic foot and generally less than 20 pounds per cubic foot. These articles also have an essentially smooth facing surface and when such articles are formed in a mold a durable skin is formed on their outer surfaces, such skin having an integrity of structure and strength characteristic of a laminate.

Foamed articles derived from the present invention can be cemented together with additional bonding agents, fillers, or reinforcing wire or fibrous materials to produce articles having a much stronger bond than articles produced by cementing particles of a ground or cut foam. Preferentially, such bonding agents, fillers, or reinforcing wire should have a coefficient of expansion similar to that of the expanded article into which they are incorporated. Additionally, expanded pellets can advantageously be used to surface concrete in color or to surface a tar roof in color without sinking. Foamed pellets as described herein, as well as articles formed by fusing together such foamed pellets may also be useful for applications combining buoyancy and impermeability in water.

The foamable granule or granules, which include the pressurized unfoamed foamable granules of the invention and the disclosed compact foamable granules as well as any other foamable granules regardless of how made, which may be molded and foamed in a closed mold in accordance with the present invention are defined herein as unfoamed, stable, vitrifiable, synthetically prepared, densified, foamable, discrete masses, having a silicon dioxide content of at least about 50 weight percent, and containing means for expanding said mass on heating homogeneously distributed throughout said mass, which mass on heating to a temperature of preferably at least about 600° C. foams to substantially homogeneous cellular structure.

The following examples, wherein all parts and percentages are to be taken by weight, illustrate the present invention but are not to be construed as limiting its scope.

Example 1

In each of a series of experiments individual charges of quartz having the following compositions by weight were comminuted to a particle size sufficient to pass through a 325 mesh screen and were individually melted under pressure in a furnace containing a nitrogen or argon inert atmosphere.

Ingredient:	Percent
SiO_2	99
Al_2O_3	0.07
CaO	0.04
MgO	0.0005
Fe_2O_3	0.03
K_2O	0.013
TiO_2	0.008
PbO_2	0.002

Each pressurized, metal mass was individually solidified by cooling to normal room temperature in the furnace at the same pressure employed during heating.

Table II shows the conditions used for melting under pressure and cooling under pressure.

TABLE II

	Fusing conditions				
Sample	Max. temp. (° C.)	Gas	Pressure, p.s.i.	Time [1]	Cooling pressure
1	1,707	N_2	1,000	70	1,000
2	1,700	N_2	750	120	750
3	1,760	Argon	1,000	60	1,000
4	1,720	N_2	500	105	500

[1] Time above 1,650° C. in minutes.

Solid unfoamed foamable vitreous masses were obtained having a glass-like appearance and densities such as, e.g. 2.15 g./cc. in sample (1) one. The density of a sample of the fused quartz not melted and pressurized in accordance with the present invention was determined to be 2.295 g./cc., thus the above solid foamable mass had a density of 94% of the solid fused quartz.

Example 2

A charge of the composition of Example 1 was mixed with 0.1 weight percent lampblack and was heated in a high pressure furnace at a temperature of between 1750° C. and 1760° C. for one hour under 800 p.s.i. of nitrogen pressure, then cooled to room temperature at the same pressure. The mass was ground to granules which had a density of 2.04 g./cc. or 89% of theoretical solid glass density.

Example 3

A charge of the composition of Example 2 including the 0.1 weight percent lampblack was heated in a high pressure furnace for 1 hour at a temperature of 1750° C. under 600 p.s.i. nitrogen pressure. The mass was cooled to room temperature at the same pressure and ground to granular form. The density of the unfoamed foamable granules was 2.02 g./cc. of 88% of theoretical.

Example 4

A charge of the composition of Example 1 was mixed with 0.1 weight percent lampblack. The mixture was heated to 1750° C. for 1 hour in a high pressure furnace under 500 p.s.i. nitrogen pressure, then cooled under the same pressure. The final ground foamable granules had a density of 2.10 g./cc. or 91.5% of theoretical.

Example 5

A quartz charge of the composition described in Example 1 was mixed with 0.1 weight percent lampblack

and was subsequently heated and melted in a high pressure furnace operating at 1800° C. under 600 p.s.i. of nitrogen pressure for one hour, then cooled to room temperature in the furnace at the same pressure, and when cool, ground to a particle or granule size of −10 |+16 mesh. The granules were solid unfoamed foamable discrete masses having a density similar to that of Example 1, i.e. 2.15 g./cc.

About 47 grams of the granules were placed in a graphite mold the dimensions of which were 1 inch by 1 inch by 6 inches, and which allowed expansion against a back pressure. The granules were heated for one hour at atmospheric pressure and a temperature of about 1675° C. After cooling, a well molded, white, foamed article having substantially all closed, uniformly spaced, fine cells, a smooth skin-like exterior surface, and a density of about 27 pounds per cubic foot was obtained.

Example 6

An inorganic glass-forming material having the following weight composition and a softening point of about 819° C. was ground up to pass a 325 mesh screen and was subsequently melted in a high pressure furnace at 1200° C. under 500 p.s.i. of CO_2 pressure for one hour.

	Percent
SiO_2	80
Al_2O_3	1.8
B_2O_3	13.0
Na_2O	4.3
K_2O	0.4
Other	0.5

The resultant solid unfoamed foamable mass was subsequently heated at a temperature of 965° C. for five minutes to form a white foam-like article having a cell size of from 0.1 to 0.8 millimeter and a density of 8 pounds per cubic foot.

Example 7

A commercially accepted soft glass having a silicon dioxide content of about 50 percent was ground to a particle size sufficient to pass through a 200 mesh screen and melted in a furnace operating at 1000° C. under 500 p.s.i. nitrogen pressure for a period of two hours. The melted mass was cooled in the pressurized furnace to normal room temperatures and subsequently reheated at atmospheric pressure. Foaming began at temperatures between 630° C. and 700° C. with a total foaming time of less than one-half hour. The resulting foamed article was nearly white with a very pale yellow cast, a density of 24 pounds per cubic foot, and a cell size essentially between 0.1 and 0.3 millimeter.

Example 8

A quartz charge having a composition as described by Example 1, was admixed with 0.1 weight percent lampblack and melted in a furnace operating at a temperature of 1750° C. under 100 p.s.i. nitrogen for a period of one hour. The resulting pressurized mass was cooled in the pressurized furnace to normal room temperatures to provide a solid unfoamed foamable mass which was subsequently ground to a particle size sufficient to allow the individual granules to pass through a 10 mesh screen and to be retained on a 16 mesh screen. The granules were then reheated at atmospheric pressure at a temperature of 1650° C. for a period of ten minutes, to form white foamed pellets having a density of about 31.5 pounds per cubic foot.

Example 9

A quartz charge having the composition as described by Example 1 was mixed with lampblack (0.1%) and melted at 1750° C. for 1 hour under 500 p.s.i. nitrogen pressure. The melt was cooled without releasing the pressure. The glass was crushed and screened. The portion retained on a 12 mesh screen but passing through an 8 mesh screen was molded at 1600° C. for 0.5 hour in a graphite mold (1⅛ x 1⅛ x 5 inch). A molding temperature above 1650° was used to produce a white foam having a large cell size. Prefoaming at 1450° for 10 minutes produced bulk density foams of 20 to 30 lbs. ft.$^{-3}$. Foam moldings having 25 lbs. ft.$^{-3}$ were made by using either unfoamed or prefoamed granules or a mixture of both.

Example 10

A composition was prepared by mixing 71.69 parts silica, 13.08 parts sodium tetraborate-5 H_2O, 7.14 parts boric oxide and 8.09 parts nepheline syenite. Analysis of the nepheline syenite gave the following: 60.4% silica, 23.6% alumina, 9.8% soda, 4.6% potash.

A quantity of the above composition was heated in a furnace operating at 1200° C. under 500 p.s.i. nitrogen pressure for one hour. The material was cooled under the same pressure and subsequently ground. The unfoamed, foamable granules were then sized by screening.

A 78.9 gram quantity of the foamable granules in a size range of minus 8, plus 12 U.S. mesh was placed in the bottom of a 2 inch x 2 inch x 10 inch stainless steel rectangular mold. The mold and granules contained therein were placed in an oven at 900° C. for 15 minutes, at which time they were removed and allowed to cool. The mold was opened to reveal a well defined block of foamed glass with a density of 6.9 lb./ft.^{3}.

Example 11

Using the same mold and foamable granules as in Example 10 the molding method was repeated with an added annealing step. 158 g. of the foamable granules were placed in the assembled mold. The mold and contents were placed in an oven at 840° C. for 15 minutes. The mold and foamed contents were removed from the oven and placed in an oven at 650° C. In 50 minutes the temperature of the oven had dropped to 575° C. at which time the mold was stripped from the foamed glass block. The annealing continued for another 70 minutes at which time the foamed block was removed from the oven at a temperature of 400° C. The foamed glass block was a well molded strong sample with a density of 11.9 lbs./ft.^{3}.

Example 12

The following materials were well mixed in a Muller mixer:

50 pounds ferro glass No. 3124
5 pounds calcium carbonate
13 pounds 5 percent gum arabic in water solution as a binder

Ferro glass No. 3124 has the following composition by weight: 14.1% CaO, 0.7% K_2O, 6.3% Na_2O, 9.9% Al_2O_3, 13.7% B_2O_3, 55.3% SiO_2.

The mud material from the Muller was balled or compacted into foamable granules in a rotating pan granulator with a heated retaining edge. The compacts were screened to a size of between 0.371 and 0.5 inch, dried in an air oven at 150° C. for one hour and then exposed for four minutes in an 830° C. oven to burn out the binder. So-prepared the compacts had an apparent density of over 50 percent of the absolute density of the glass mixture being employed.

Molding was carried out by taking such balls out of storage, putting a predetermined amount into a 2 x 3 x 6 inch mold, and heating for 16 minutes at 800° C. The balls foamed and filled the mold. The molding was annealed for one hour at 435° C. and cooled at the rate of 2° C. per minute. The foamed article has the following physical properties:

Density	lb./ft.^{3}	9.42
Cell size	mm	0.6
Percent open cell (approx.)		18
Compressive strength	p.s.i.	129.6

What is claimed is:

1. A method for preparing a solid, glass-like, unfoamed, foamable, pressurized mass comprising: heating a comminuted inorganic glass-forming material having a silicon dioxide content of at least about 50 weight percent under an applied gas pressure of at least 100 p.s.i. of a gas which is essentially unreactive with said glass-forming material to a temperature sufficient to melt said material into a vitreous mass containing said gas undissolved but entrapped and compressed therein and, maintaining said vitreous mass under an applied gas pressure of at least about 100 p.s.i. until said mass has cooled to a solidified, pressurized, essentially gas impermeable, unfoamed but foamable glass-like material containing undissolved, entrapped, compressed gas.

2. The method of claim 1 wherein said applied gas pressure is maintained between about 200 to about 800 p.s.i. during melting of the comminuted inorganic glass-forming material and cooling of said unfoamed, foamable, vitreous mass.

3. The method of claim 1 including the additional step of granulating the solidified, vitreous, pressurized material.

4. A method of producing a foamed cast article conforming in shape to the mold cavity configuration in which cast consisting essentially of: introducing unfoamed, synthetically prepared, discrete, foamable granules containing undissolved, entrapped, compressed gas and having a silicon dioxide content of at least about 50 weight percent and containing means for expanding upon heating said discrete granules distributed homogeneously throughout into a closed mold in a predetermined amount upon foaming to fill said mold cavity; heating said mold and contents at least to the softening point of the granules to effect foaming of said discrete, unfoamed, foamable granules, thereby to provide a foamed cast article conforming in shape to the mold cavity.

5. A method of heat forming a foamed glass article comprising: introducing unfoamed, foamable, discrete granules containing undissolved, entrapped, compressed gas into a mold cavity in an amount to obtain upon foaming a foamed glass article of a predetermined density and a shape conforming substantially to the mold cavity configuration, closing the mold containing said granules, heating said mold and contents to a temperature of from about 600° C. to about 1800° C. to effect foaming of the granules, and cooling the foamed article resulting at least to a point where its structure is substantially rigidly self-supporting.

6. A solid pressurized, unfoamed, vitreous, foamable mass having a silicon dioxide content of at least 50 weight percent containing undissolved entrapped, compressed gases.

7. The solid, pressurized, unfoamed, foamable mass of claim 6 containing a small amount of a gas-generating substance capable of generating gas at a temperature sufficient to soften said solid vitreous mass.

8. The unfoamed, foamable, pressurized mass of claim 6 characterized by having a density of at least about 2.00 grams per cubic centimeter.

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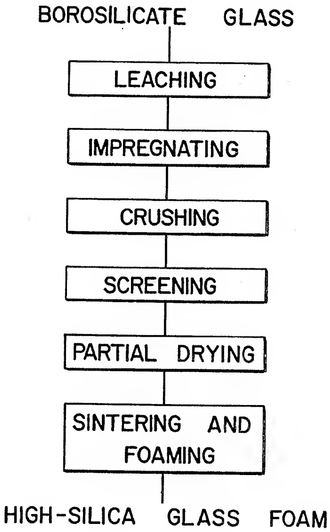

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HIGH-SILICA GLASS FOAM METHOD

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U.S. Cl. *65—22* 9 Claims

ABSTRACT OF THE DISCLOSURE

A method of making a high-silica glass foam by forming a body of borosilicate glass containing not more than about 70% by weight of silica, the glass being capable of separating into a silica-rich phase and a silica-poor phase, treating the glass with a mineral acid to remove the silica-poor phase and leave a high silica body having a porous structure, impregnating the porous body with a boric oxide solution, crushing and screening the porous body, drying the particulated material to remove excess water, and sintering and foaming the particulated material to form a fused, a low expansion, high silicaglass foam.

Foamed or cellulated refractory bodies, that is, inorganic heat resistant bodies expanded by the internal development of non-connecting gas filled cells while the material is in the coalesced or fused state, are well known. Conventional foamed glass products having densities on the order of about 0.15 to 0.30 gram/cc., have been used commercially to provide buoyancy, lightweight and thermal insulation in conjunction with resistance to heat and moisture penetration.

These materials are customarily produced from premelted glass. In general, the process involves premelting a suitable glass composition, pulverizing the glass in admixture with chemically reactable gas producing agents, such as a carbon reducing agent together with an oxidizing agent, depositing a thin layer of the pulverized mixture in a closed pan, heating to the foaming temperature of about 800–900° C., and then annealing over a period of several hours.

Furthermore, consolidated high silica glassware is well known under the designation of "96% silica glass." Such a consolidated nonporous glass body is produced from a porous glass body corresponding in shape and composition, but larger in size, and characterized by a multiplicity of intercommunicating, submicroscopic pores. The basic production steps involved and a particularly suitable family of parent borosilicate glasses are described in U.S. Pat. 2,221,709 issued to Hood et al.

Briefly the method includes (1) forming or fabricating an article of desired shape from a parent borosilicate glass; (2) thermally treating the glass article at a temperature of 500–600° C. for a period of time to separate the glass into a silica-rich phase and a silica-poor phase; (3) dissolving or leaching the silica-poor- phase usually with acid to produce a porous structure composed of the silica-rich phase; (4) washing to remove leaching residue, (5) drying; and (6) thermally consolidating the porous body into a nonporous vitreous article by heating without fusion. The consolidated article has a general shape of the original glass article but is reduced by about ⅓ in volume. The maximum consolidation temperature is above 900° C. and on the order of 1200–1300° C. in higher silica content glasses. The pore size of the porous glass before consolidation is generally within the vicinity of 45–90° A.

Quite surprisingly, we have now discovered a method of making a fused high silica glass foam from leached porous glass particles. The foam is useful in making

radomes having broad band frequencies especially in the microwave spectrum. The uniformity of electrical properties combined with the low loss factor over a widely extended temperature range are particularly important properties of the foam for such application. Other characteristics which offer advantages over conventional foams include interconnecting pores, low thermal expansion extremely low alkali metal oxide content, high use temperatures, resistance to devitrification, and uniformity of structure. Further, since no cellulating agents are used the foamed product is free from undesirable contamination.

In accordance with the present invention, we have discovered a method of making a high-silica glass form by forming a body of borosilicate glass containing a maximum of 70% by weight of silica, the glass being capable of separating into a silica-rich phase and a silica-poor phase, treating the glass to remove the silica-poor phase, and leave a high silica body having a porous structure impregnating the porous body with a boric oxide solution, crushing and screening the porous body, drying the particulated material to remove excess water, and sintering and foaming the particulated material to form a fused, low-expansion, high-silica glass foam. Typically the foamed product has a thermal expansion coefficient of about $8 \times 10^{-7}/°$ C.

The accompanying drawing is a flow sheet of the novel process, which while not intended as a definition essentially illustrates the invention.

The base glass used in this process is a borosilicate glass and may be designated by the general formula $R_2O—B_2O_3—SiO_2$, wherein R is an alkali metal. The glasses must be capable of phase separating into a silica-rich phase and a silica-poor phase and they must be leachable without a heat treatment using a conventional mineral acid, e.g. nitric acid, sulfuric acid or hydrochloric acid. The glass compositions, which may be used herein as given in weight percent on the oxide basis as calculated from the batch and are as follows:

Ingredient	Percent: Broad range	Percent: Preferred range
SiO_2	55–70	58–65
B_2O_3	20–40	20–30
R_2O	1–10	4–9
Al_2O_3	0–5	0–3

The silica content should not exceed about 70% by weight, since glasses containing greater amounts require a preliminary heat treatment prior to leaching. Moreover, when the silica content exceeds the preferred range, autoclaving and using hot acids may be required. It is also recommended that as the silica content approaches the higher levels within the prescribed ranges, the glass should be ground and leached in the form of particles or granules. A specific example of a glass illustrating the invention and given in weight percent is as follows:

Ingredient:	Amount, percent
SiO_2	61.6
Na_2O	8.04
B_2O_3	28.2
Al_2O_3	1.9
As_2O_3	0.3

The borosilicate glass in the form of tubing or particles is initialy subjected to an acid leaching treatment. Useful acids are dilute solutions, typically in the range of 1–2 normal solutions of mineral acids, e.g. HCl, H_2SO_4, HNO_3. However, hydrofluoric acid should not be used since it dissolves the silica-rich phase. The temperature of the leaching bath is generally about 90–100° C. with about

95° C. being preferred. As the temperature of the bath falls below 90° C., there is less thorough extraction and a substantial increase in the extraction time. We have found that below 85° C., the rate of leaching becomes too slow. The leaching time is to some extent dependent upon the concentration of the acid and the temperature of the bath. A typical leaching schedule involves leaching the glass for two days in a 1.5 N solution of nitric acid at about 95° C., then rinsing in a fresh solution of the same acid strength and finally rinsing in a dilute, 0.2 N, solution of nitric acid for one day. Sometimes prior to leaching, it may be desirable to subject the glass to a preliminary etch treatment to remove the surface skin and thereby permit a more uniform penetration of acid into the body of the glass. Preliminary etching is recommended for thick walled tubing and also when the surface of the glass has become contaminated on storage. A typical preliminary etching may be performed by dipping in a 15 wt. percent $NH_4F \cdot HF$ solution for 10 minutes.

The porous glass body obtained after the leaching step must have a very fine network of pores. The pore size must be in the range of 10–25 A. In order to obtain such a fine network of pores, heat treatment prior to leaching must be avoided. The reason will become readily apparent when we discuss the foaming mechanism. Briefly, the fine pores entrap moisture which serves to expand the foam. In comparison, phase separating glasses which have been subjected to a prior heat treatment yield porous glass with large pores, e.g. 50 A. and greater, from which moisture can escape.

The next step involves impregnating the porous glass with a boric acid solution which acts as a flux and becomes incorporated in the glass structure as B_2O_3. Further, the presence of boric acid reduces the sintering temperature and aids in the closing of the pores to minimize escape of moisture. Omission of the boric acid impregnation results in a weak foam. The boric acid, to some extent, also aids foaming since upon decomposition moisture is given off as shown in the equation:

$$2H_3BO_3 \rightarrow B_2O_3 + 3H_2O$$

In preparing the solution, it should be taken into account that the solubility of boric acid in water increases considerably at elevated temperatures and is about 27.6 g./100 cc., H_2O at 100° C. For practical purposes the solution should be at least slightly below the saturation point. We prefer to use a concentration of 15–20 g. H_3BO_3/100 cc. H_2O. Hot impregnation is preferred at temperatures of 90–100° C. The time for impregnation is usually at least three hours with longer times being permissible. After impregnation, the sample is air dried at room temperature. Other conventional drying techniques, e.g. dessication, may also be used.

The dried material is crushed into small particles taking care not to introduce contaminants. The material is quite friable at this point and may be particulated using a roll crusher. Good yields of fractions of both coarse and fine particles are obtained when the gap setting of the rolls is about 0.090 in. The setting may be adjusted to give coarser or fined particles. However, ball milling is not desirable since this results in excessive fines and tends to introduce contamination. When the starting material is in the form of particles, crushing may be eliminated.

The crushed particles are now screened by conventional procedures. The density of the foam is directly related to the particle size, i.e. the finer the particles, the denser the foam and vice versa. This may be explained by the fact that smaller particles pack more densely and degas easier, and in addition, then tend to entrap less moisture. Typical values for particle sizes given in terms of U.S. Standard Sieves for specific foam densities and the percentages by weight are listed in the table below. It should be noted that these values are also to some extent influenced by the firing temperature, the impregnation time, and the geometry of the firing mold.

TABLE I

Grain size vs. density

Density g./cc.:	Mesh classification:
0.22	−4 +20
0.33	50% −20 +40 50% +20
0.45	−20 +40
0.55	−20 +60
0.55	50% −20 +40 50% −60 +fines
0.62	50% −40 +60 50% −20 +60
0.70	75% −60 +fines 25% −20 +40
0.70	75% −40 +60 25% −20 +60
0.80	−40 +60
0.89	90% −60 +fines 10% −20 +40
1.0	90% −60 +fines 10% −20 +60
1.0	75% −40 +fines [1] 25% −20 +60

[1] Nonporous glass particles having the identical composition.

The porous particles are then subjected to a particle drying procedure to remove some of the mechanically held water. The purpose is to prevent gas pockets or voids from being formed when the porous glass particles are flash-fired. If the glass particles are not partially dried, a nonuniform foam is produced. It is recommended to place the particles in a furnace mold that will also be used in the final sintering step. The samples are preheated at a temperature ranging from about 200–500° C., but the temperature should not exceed 600° C. The heating time varies from 2–5 hours depending on the thickness and size of the glass particles and the depth of the charge being dried.

The porous glass particles, which have previously been partially dried, are then sintered and foamed almost simultaneously. The foaming agent is water vapor which is derived primarily from the water of constitution (silanol groups) and also from the decomposition of boric acid. Expansion of the porous glass granules and the sintering of the granules occurs at temperatures of 1300–1425, with about 1400° C. being preferred. The glass must be flash fired so that the pores are closed very rapidly to prevent escape of the water vapor liberated by the glass and the boric acid. The particles expand near the final firing temperature. At this point the glass is fluid enough to permit movement and is in a viscosity range so that it can expand, but the temperature is still below the softening point of the glass.

Specific procedures for molding foamed articles are given in the following examples.

EXAMPLE 1

Porous particles of a leached borosilicate glass were impregnated with an aqueous solution of boric acid. The dried particles having a grain size of −20 to +40 mesh U.S. Standard Sieve and a pore size of 10–25 A were placed in a Vycor tray lined with an alumina-silica ceramic fiber. The tray was placed into an oven at a temperature of 500° C. for a period of 2 hours. Thereafter the tray was immediately transferred to an oven at a temperature of 1400° C. for a period of 2 hours. The resulting foam had a density of 0.5 gms./cc. The foam was then machined to the desired shape.

EXAMPLE 2

A slip casting mixture was prepared using an aqueous vehicle, presaturated with boric acid, and consolidated 96% silica particles substantially passing through a 325 mesh screen. To this mixture were added porous glass

particles having a size of −20 to +60 mesh sieve and which had been impregnated with boric acid as described hereinabove.

The final mixture contained 40% by weight porous glass particles and 60% by weight consolidated glass particles based on the ceramic content of the slip. Thereafter the new mixture was dispersed by rolling in a six gallon plastic bottle for 16 hours and drain cast in a conically shaped mold to a piece having a thickness of ⅝ inch. Any loss of boric acid during slip casting was considered to be negligible. The piece was allowed to dry at room temperature for 24 hours and then placed under radiant heaters for about 3 days.

The piece was thereafter preheated for 16 hours at a temperature of 450° F. and thereafter fired in a kiln at 1350° C. The resulting product had a density of 0.47 gm./cc.

Unlike the conventional glass foams discussed hereinabove, the low-expansion, high-silica glass foams do not require annealing.

It will be appreciated that the invention is not limited to the specific details shown in the illustrations and examples, and that various modifications may be made within the ordinary skill in the art without departing from the spirit and scope of the invention.

We claim:

1. A method of making a high-silica glass foam comprising the steps of:
 (a) forming a body of a borosilicate glass containing a maximum of 70% by weight of silica capable of separating into a silica-rich phase and a silica-poor phase;
 (b) leaching the silica-poor phase to produce a porous high-silica body having a pore size in the range of 10–25 A.;
 (c) impregnating the porous body with an aqueous boric acid solution at a temperature of 90–100° C. for a sufficient time;
 (d) particulating the impregnated glass;
 (e) drying the particulated material at a temperature of 200–500° C. to remove excess water; and
 (f) foaming the particulated material at an elevated temperature of about 1300–1425° C. to form a fused foamed glass body.

2. The method of making the glass foam of claim 1, wherein the density of the product is in the range of 0.22–1.0 gm./cc.

3. The method of claim 1, wherein said boric acid solution contains about 15–20 grams H_3BO_3 per 100 cc. of water.

4. The method of claim 1, wherein said dried particulated material is molded into a foamed article.

5. The method of claim 1, wherein the particulated material is slip cast prior to the foaming step.

6. The method of claim 2, wherein the leaching step is performed using a dilute mineral acid solution.

7. The method of claim 1, wherein the borosilicate glass consists essentially as calculated from the batch in weight percent on the oxide basis of:

Ingredient:	Range, percent
SiO_2	55–70
B_2O_3	20–40
R_2O	1–10
Al_2O_3	0–5

wherein R is an alkali metal.

8. The method of claim 7 wherein said borosilicate glass consists essentially as calculated from the batch in weight percent on the oxide basis of:

Ingredient:	Range, percent
SiO_2	58–65
B_2O_3	20–30
R_2O	4–9
Al_2O_3	0–3

wherein R is an alkali metal.

9. The method of claim 8 wherein said composition consists essentially of:

Ingredient:	Amount
SiO_2	61.6
Na_2O	8.04
B_2O_3	28.2
Al_2O_3	1.9
As_2O_3	0.3

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PRODUCTION OF CELLULATED GLASS

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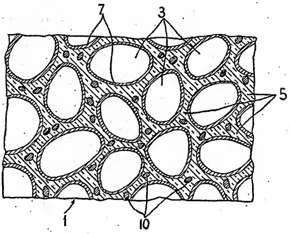

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PRODUCTION OF CELLULATED GLASS

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Application March 21, 1952, Serial No. 277,917

15 Claims. (Cl. 106—40)

This invention relates to cellular glass bodies of improved cell structure and more uniform cell wall thickness which are suitable for use as insulating materials and it has particular relation to cellular glass bodies formed by bloating or cellulating partially fused glass.

It is known that highly cellulated glass suitable for use as an insulating material and other applications, may be prepared by heating a mixture of finely pulverized glass and an agent designed to give off gases at temperatures near the melting point or sintering point of the glass. A gassing agent which has been found to be quite useful is pulverulent carbon which may be used in the form of pulverized carbon, lamp black, carbon black, channel black, powdered coal, charcoal or graphite or any other form of finely divided carbon that is readily combustible. Other suitable gassing agents which have been used include calcium sulfate, calcium carbonate and carbon containing compounds such as urea.

One of the problems encountered in the manufacture of these cellulated glass bodies is the production of a cellulated glass body wherein the cell walls of the article are of uniform thickness and maximum strength. The properties of uniform thickness and maximum strength of cell walls are important in the manufacture of the cellulated article as well as in its use. During the manufacture of the cellulated glass article, it is desired to have the cell walls formed of uniform thickness and maximum strength by the expanding gases so as to prevent premature breakdown of the cell walls during the cellulation. Uniform thickness and maximum strength of cell walls are important in the use of the cellulated glass bodies to enable the bodies to carry higher loads under compression.

In accordance with the present invention, a cellular glass article is provided which has improved durability, low thermal conductivity, higher structural strength for a given density, a finer cell structure and more uniform cell wall thickness. This article is composed of a cellulated body of glass having a plurality of non-communicating cells filled with a gas such as CO_2 and having a metal such as molybdenum, tungsten or vanadium interspersed in and on the cell walls.

A sectional view of a slab of the cellulated material is shown in the drawing. The material is made up of cellulated glass 1 having a plurality of non-communicating cells 3 filled with a gas. The walls 5 of the cells are partially or fully coated with a fine film of metal 7 such as molybdenum, tungsten or vanadium. Also present in the cell walls 5 are small amounts of the metal 7 as shown at 10.

For purposes of illustration, the slab of cellulated material has been enlarged many times. The average size of a cell is usually about 1/32 of an inch in diameter, however, such size is designated merely by way of illustration and not by way of limitation. The cells can be quite small or much larger, for example, 1/4 inch in diameter or larger. Large cell size gives a product of lower density but also lower compressive strength.

The cellular glass which is the subject of this invention, is produced by commingling glass, a gassing agent and an oxide of a metal having a high melting and boiling point such as an oxide of molybdenum, tungsten or vandium all in pulverulent form, heating the mixture to a temperature at which it sinters and coheres and at which the gassing agent and the metal oxide such as molybdenum oxide react to produce gases which expand to form minute, non-communicating cells within the glass, cooling the cellulated glass and thereafter annealing it.

In the prodnction of the cellulated glass, a glass of conventional formulation may be employed as the principal ingredient of the batch which is prepared for cellulation. For example, it may comprise ordinary lime-soda glass such as is employed in windows, and which consists essentially of silica, lime and soda in appropriate amounts, as is well known. This glass may also be modified by the inclusion of certain amounts of other ingredients, such as alumina, magnesia, borax, etc.

The glass is finely pulverized, for example, to a particle size that will pass a screen of 200 mesh or finer. This finely pulverized material may be ground with the gassing agent, e. g., finely divided carbon. The amount of finely divided carbonaceous material is susceptible of certain variation but, in any event, the amount required is never very large, usually being within the range of 0.1 to 5 per cent by weight of the batch. For example, in lamp black, the ratio will be approximately 0.5 to 1 per cent by weight, although slightly larger or smaller amounts may be employed. With carbon black, the ratio is even smaller, e. g., 0.15 to 0.2 per cent.

Various oxides of the metals mentioned above may be added to the pulverulent mixture of glass and gassing agent. Molybdenum anhydride has been found to be preferable, but molybdenum sesqui oxide, dioxide, and pentoxide, tungsten di- and trioxide and the various vanadium oxides have been found to be suitable. The amount of molybdenum oxide which is added to the mixture of pulverulent glass and gassing agent prior to cellulation is preferably within 0.05 to 1.0 per cent by weight of the three-component mixture, but larger amounts may be used. The components of the mixture above described are very carefully admixed, for example, by gradual or periodic addition of the carbon and molybdenum oxide to the glass cullet as it is being ground upon a ball mill.

As an alternative to the procedure described above a glass already containing the metal oxide may be pulverized and mixed with the gassing agent. The amount of metal oxide necessary when formulated with the glass will be slightly larger than when incorporated separately.

The mixture of glass, molybdenum oxide and gassing agent or agents is ground as fine as practicable upon the ball mill and is then ready for heating to form cellular glass. This heating operation is performed preferably in a reducing atmosphere and may be done by placing the mixture in appropriate amounts in suitable molds of sufficiently refractory material. Molds of stainless steel containing high percentages of nickel and chromium are especially suitable for the purpose. The molds are so constructed that they can be substantially closed, thus protecting the mixture to be sintered from oxidation during the heating operation. The molds should usually be approximately 1/7 filled, though of course, this will depend to some extent upon the degree of cellulation desired in the final product. In any event the amount should be adjusted so as to just fill the mold when full cellulation is attained.

The molds may be heated in any convenient furnace, but in commercial operation a tunnel furnace having suitable conveyor apparatus, such as a train of rollers designed to carry the molds slowly through the heating zone is to be desired. The heating operation is con-

ducted slowly because of the low conductivity of the powdered materials. Usually it will be completed within a period of about 3 to 5 hours depending upon the thickness and size of the bodies to be formed. The temperature of heating should be sufficient to soften and sinter together the particles of glass and also to cause the gassing agent to react. This mass should never be completely melted. The temperature of heating will vary with individual glasses, but usually will be in or near the range of 1400 to 1800° F.

The bodies of cellular material as obtained by the foregoing process should be cooled slightly externally, stripped from the molds and annealed in order to relieve internal stresses in the glass. The products after annealing are trimmed to size and shape.

Such process produces bodies of a high degree of uniform cellularity. The addition of a metal oxide such as a molybdenum oxide to the pulverulent glass and gassing agent changes the surface tension of the cellulating glass in such manner that a minimum amount of cell breakdown occurs during cellulation, thus producing a finer cell structure with more uniform wall thickness. The specific gravity of the product will be approximately within a range of 0.14 to 0.18. Because of the large amount of entrapped gases, the resistance to transmission of heat is greater than that of less highly cellulated products.

The products are characterized by a high structural strength for a given density. Such high structural strength is due to the high degree of cellulation as well as uniformity of cellulation and uniformity of cell wall thickness which is rendered possible by the addition of the metal oxide to the pulverulent batch which is used in the manufacture of the glass. The high structural strength is also believed to be due to a coating of the metal on the walls of the individual cells or to particles of the metal in the actual structure of the walls. The metal results from the reaction of the gassing agent with the metal oxide during the heating and cellulating. The durability of the product is also improved by the presence of the metal as described above.

The invention has been described with respect to the cellulation of glass but it is intended to be operable with respect to the cellulation of other materials such as in the cellulation of slag, silica, glass batch materials, natural mineral silicates, etc.

Althrough the present invention has been described with reference to the specific details of certain embodiments thereof, it is not intended that such details shall be regarded as limitations upon the scope of the invention except insofar as included in the accompanying claims.

This application is a continuation-in-part of my copending application, Serial No. 734,241, filed March 12, 1947, now U. S. Patent No. 2,600,525, entitled "Cellular Glass of Increased Durability."

I claim:

1. An article of manufacture which comprises a cellulated body of glass having a plurality of non-communicating cells filled with a gas and having a coating on the cell walls of a metal selected from the group consisting of molybdenum, tungsten and vanadium.

2. An article of manufacture which comprises a cellulated body of glass having a plurality of non-communicating cells filled with a gas and having a coating of molybdenum of the cell walls.

3. An article of manufacture which comprises a cellulated body of glass having a plurality of non-communicating cells filled with carbon dioxide and having a coating of molybdenum on the cell walls.

4. An article of manufacture which comprises a cellulated body of glass containing molybdenum and having a plurality of non-communicating cells filled with a gas.

5. A method of producing cellular glass which comprises mixing a finely pulverized glass containing 0.05 to 1.0% of metal oxide selected from the group consisting of oxides of molybdenum, tungsten and vanadium with 0.1 to 5% carbon, heating the mixture in a mold to a temperature sufficient to soften and sinter together the particles of glass and to cause the carbon to react to form gases until a cellular glass of desired size is formed and cooling the cellular glass.

6. A method of producing cellular glass which comprises mixing a finely pulverized glass containing 0.05 to 1.0% of molybdenum oxide with 0.1 to 5% pulverulent carbon, heating the mixture in a mold to a temperature sufficient to soften and sinter together the particles of glass and to cause the carbon to react to form gases until a cellular glass of desired size is formed and cooling the cellular glass.

7. A method of producing cellular glass which comprises intimately mixing finely pulverized glass, 0.1 to 5% carbon and 0.05 to 1.0% of metal oxide selected from the group consisting of oxides of molybdenum, tungsten and vanadium, heating the mixture in a mold to a temperature sufficient to soften and sinter together the particles of glass and to cause the carbon and metal oxide to react to produce gases, discontinuing the heating when the gases developed within the glass increase the volume thereof to the desired extent whereby cells are formed which are noncommunicating, cooling and annealing the cellular glass product thus formed.

8. A method of producing cellular glass which comprises intimately mixing glass, 0.1 to 5% carbon and 0.05 to 1.0% molybdenum oxide, all in pulverulent form, heating the mixture in a mold to a temperature sufficient to soften and sinter together the particles of glass and to cause the carbon and molybdenum oxide to react to form gases, discontinuing the heating when the gases developed within the glass increase the volume thereof to the desired extent whereby noncommunicating cells are formed, cooling and annealing the cellular glass.

9. An article of manufacture which comprises a cellulated body of glass having a plurality of non-communicating cells filled with a gas and having a coating of tungsten on the cell walls.

10. An article of manufacture which comprises a cellulated body of glass having a plurality of non-communicating cells filled with a gas and having a coating of vanadium on the cell walls.

11. A batch suitable for forming cellular, vitreous products which consists essentially of a finely pulverized glass, 0.1 to 5% carbon and from 0.05 to 1.0% by weight of a metal oxide selected from the group consisting of oxides of molybdenum, tungsten and vanadium.

12. A batch suitable for forming cellular, vitreous products which consists essentially of finely pulverized glass containing 0.05 to 1.0% of metal oxide selected from the group consisting of oxides of molybdenum, tungsten and vanadium, and 0.1 to 5% carbon.

13. A batch suitable for forming cellular, vitreous products which consists essentially of a finely pulverized glass, 0.1 to 5% carbon and from 0.05 to 1.0% by weight of molybdenum oxide.

14. A batch suitable for forming cellular glass which consists essentially of an intimate, finely pulverized mixture of glass, 0.1 to 5% carbon designed to give off gases to bloat the mixture at the sintering point of the glass and from 0.5 to 1.0% by weight of tungsten oxide.

15. A batch suitable for forming cellular glass which consists essentially of an intimate, finely pulverized mixture of glass, 0.1 to 5% carbon designed to give off gases to bloat the mixture at the sintering point of the glass and from 0.05 to 1.0% by weight of vanadium oxide.

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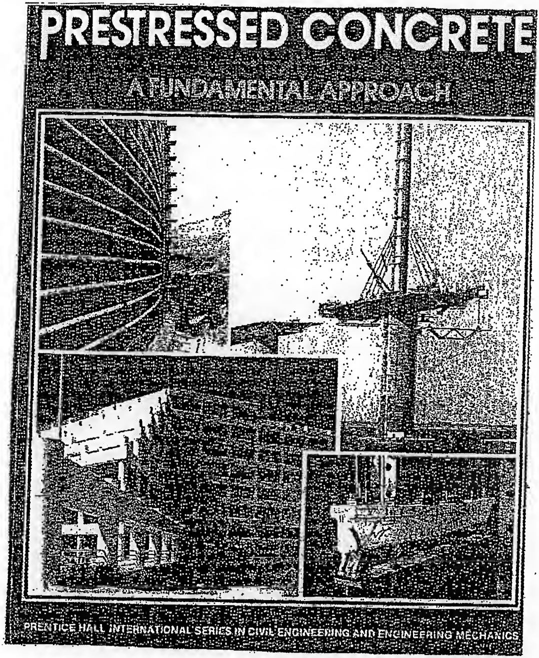

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applications. The success in the development and construction of all these landmark structures has been due in no small measure to the advances in the technology of materials, particularly prestressing steel, and the accumulated knowledge in estimating the short- and long-term losses in the prestressing forces.

1.3 BASIC CONCEPTS OF PRESTRESSING

1.3.1 Introduction

The prestressing force P that satisfies the particular conditions of geometry and loading of a given element (see Figure 1.2) is determined from the principles of mechanics and of stress-strain relationships. Sometimes simplification is necessary, as when a prestressed beam is assumed to be homogeneous and elastic.

Consider, then, a simply supported rectangular beam subjected to a *concentric* prestressing force P as shown in Figure 1.2(a). The compressive stress on the beam cross section is uniform and has an intensity

$$f = -\frac{P}{A_c} \tag{1.1}$$

where $A_c = bh$ is the cross-sectional area of a beam section of width b and total depth h. A *minus* sign is used for compression and a *plus* sign for tension throughout the text. Also, bending moments are drawn on the tensile side of the member.

If external transverse loads are applied to the beam, causing a maximum moment M at midspan, the resulting stress becomes

$$f^t = -\frac{P}{A} - \frac{Mc}{I_g} \tag{1.2 a}$$

and

$$f_b = -\frac{P}{A} + \frac{Mc}{I_g} \tag{1.2 b}$$

where f^t = stress at the top fibers
f_b = stress at the bottom fibers
$c = \frac{1}{2}h$ for the rectangular section
I_g = gross moment of inertia of the section ($bh^3/12$ in this case)

Equation 1.2b indicates that the presence of prestressing-compressive stress $-P/A$ is reducing the tensile flexural stress Mc/I to the extent intended in the design, either eliminating tension totally (even inducing compression), or permitting a level of tensile stress within allowable code limits. The section is then considered uncracked and behaves elastically: the concrete's inability to withstand tensile stresses is effectively compensated for by the compressive force of the prestressing tendon.

The compressive stresses in Equation 1.2a at the top fibers of the beam due to prestressing are compounded by the application of the loading stress $-Mc/I$, as seen in Figure 1.2(b). Hence, the compressive stress capacity of the beam to take a substantial external load is reduced by the *concentric* prestressing force. In order to avoid this limitation, the prestressing tendon is placed *eccentrically* below the neutral

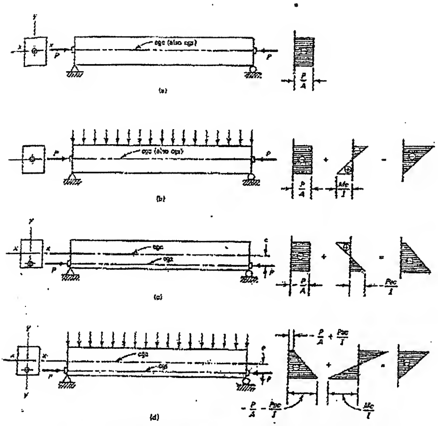
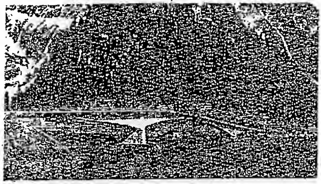


Figure 1.2 Concrete fiber stress distribution in a rectangular beam with straight tendon. (a) Concentric tendon, prestress only. (b) Concentric tendon, self-weight added. (c) Eccentric tendon, prestress only. (d) Eccentric tendon, self-weight added.

axis at midspan, to induce tensile stresses at the top fibers due to prestressing. (See Figure 1.2(c), (d).) If the tendon is placed at eccentricity e from the center of gravity of the concrete, termed the *cgc line*, it creates a moment Pe, and the ensuing stresses at midspan become

$$f^t = -\frac{P}{A_c} + \frac{Pec}{I_g} - \frac{Mc}{I_g} \qquad (1.3\,a)$$

$$f_b = -\frac{P}{A_c} - \frac{Pec}{I_g} + \frac{Mc}{I_g} \qquad (1.3\,b)$$



Douglas Bridge Crossing, Gastineau Channel, Juneau and Douglas, Alaska. (*Courtesy, Prestressed Concrete Institute.*)

Since the support section of a simply supported beam carries no moment from the external transverse load, high tensile fiber stresses at the top fibers are caused by the eccentric prestressing force. To limit such stresses, the eccentricity of the prestressing tendon profile, the *cgs line*, is made less at the support section than at the midspan section, or eliminated altogether, or else a negative eccentricity above the cgc line is used.

1.3.2 Basic Concept Method

In the basic concept method of designing prestressed concrete elements, the concrete fiber stresses are *directly* computed from the external forces applied to the concrete by longitudinal prestressing and the external transverse load. Equations 1.3a and b can be modified and simplified for use in calculating stresses at the initial prestressing stage and at service load levels. If P_i is the initial prestressing force before stress losses, and P_e is the effective prestressing force after losses, then

$$\gamma = \frac{P_e}{P_i}$$

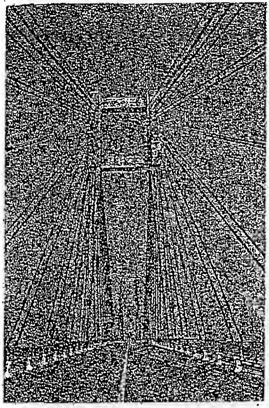
can be defined as the residual prestress factor. Substituting r^2 for I_g/A_c in Equations 1.3, where r is the radius of gyration of the gross section, the expressions for stress can be rewritten as follows:

(*a*) *Prestressing Force Only*

$$f^t = -\frac{P_i}{A_c}\left(1 - \frac{ec_t}{r^2}\right) \qquad (1.4a)$$

$$f_b = -\frac{P_i}{A_c}\left(1 + \frac{ec_b}{r^2}\right) \qquad (1.4b)$$

where c_t and c_b are the distances from the center of gravity of the section (the cgc line) to the extreme top and bottom fibers, respectively.



Tianjin Yong-He cable-stayed prestressed concrete bridge, Tianjin, China, the largest span bridge in Asia, with a total length of 1,673 ft and a suspended length of 1,535 ft, was completed in 1988. (*Credits* Owner: Tianjin Municipal Engineering Bureau. General contractor: Major Bridge Engineering Bureau of Ministry of Railways of China. Engineer for project design and construction control guidance: Tianjin Municipal Engineering Survey and Design Institute, Chief Bridge Engineer, Bang-yan Yu.)

(b) Prestressing Plus Self-weight

If the beam self-weight causes a moment M_D at the section under consideration, Equations 1.4a and b respectively become

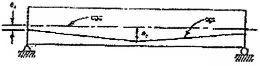
$$f^t = -\frac{P_i}{A_c}\left(1 - \frac{ec_t}{r^2}\right) - \frac{M_D}{S^t} \qquad (1.5\,a)$$

and

$$f_b = -\frac{P_i}{A_c}\left(1 + \frac{ec_b}{r^2}\right) + \frac{M_D}{S_b} \qquad (1.5\,b)$$

where S^t and S_b are the moduli of the sections for the top and bottom fibers, respectively.

The change in eccentricity from the midspan to the support section is obtained by raising the prestressing tendon either abruptly from the midspan to the support, a process called harping, or gradually in a parabolic form, a process called draping.



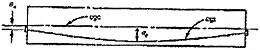


Figure 1.3 Prestressing tendon profile. (a) Harped tendon. (b) Draped tendon.

Figure 1.3(a) shows a harped profile usually used for pretensioned beams and for concentrated transverse loads. Figure 1.3(b) shows a draped tendon usually used in post-tensioning.

Subsequent to erection and installation of the floor or deck, live loads act on the structure, causing a superimposed moment M_s. The full intensity of such loads normally occurs after the building is completed and some time-dependent losses in prestress have already taken place. Hence, the prestressing force used in the stress equations would have to be the effective prestressing force P_e. If the total moment due to gravity loads is M_T, then

$$M_T = M_D + M_{SD} + M_L \tag{1.6}$$

where M_D = moment due to self-weight
M_{SD} = moment due to superimposed dead load, such as flooring
M_L = moment due to live load, including impact and siesmic loads if any

Equations 1.5 then become

$$f^t = -\frac{P_e}{A_c}\left(1 - \frac{ec_t}{r^2}\right) - \frac{M_T}{S^t} \tag{1.7 a}$$

$$f_b = -\frac{P_e}{A_c}\left(1 + \frac{ec_b}{r^2}\right) + \frac{M_T}{S_b} \tag{1.7 b}$$

Some typical elastic concrete stress distributions at the critical section of a prestressed flanged section are shown in Figure 1.4. The tensile stress in the concrete in part (c) permitted at the extreme fibers of the section cannot exceed the maximum permissible in the code, e.g., $f_t = 6\sqrt{f'_c}$ in the ACI code. If it is exceeded, bonded non-prestressed reinforcement proportioned to resist the total tensile force has to be provided to control cracking at service loads.

1.3.3 C-Line Method

In this line-of-pressure or thrust concept, the beam is analyzed as if it were a plain concrete elastic beam using the basic principles of statics. The prestressing force is considered an external compressive force, with a constant tensile force T in the tendon

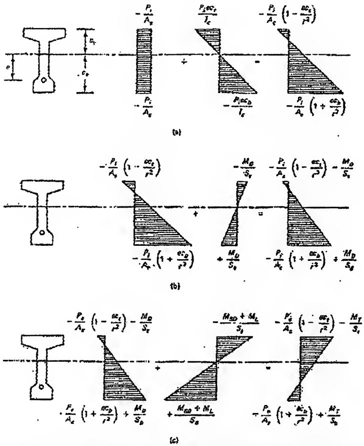


Figure 1.4 Elastic fiber stresses due to the various loads in a prestressed beam. (a) Initial prestress before losses. (b) Addition of self-weight. (c) Service load at effective prestress.

throughout the span. In this manner, the effects of external gravity loads are disregarded. Equilibrium equations $\Sigma H = 0$ and $\Sigma M = 0$ are applied to maintain equilibrium in the section.

Figure 1.5 shows the relative line of action of the compressive force C and the tensile force T in a reinforced concrete beam as compared to that in a prestressed concrete beam. It is plain that in a reinforced concrete beam, T can have a finite value only when transverse and other external loads act. The moment arm a remains basically constant throughout the elastic loading history of the reinforced concrete

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No. : 10/625,102 Confirmation No. : 8891

Applicant : Pedro M. Buarque de Macedo

Filed : July 22, 2003

TC/A.U. : 3673

Examiner : Michael Safavi

Docket No. : 50699/11

Customer No. : 1912

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DECLARATION UNDER 37 C.F.R. § 1.132

Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, PEDRO M. BUARQUE DE MACEDO, declare that:

1. I am the inventor and owner of the above-referenced U.S. Patent Application Serial No. 10/625,102 filed on July 22, 2003 in the name of Pedro M. Buarque de Macedo and entitled "PRESTRESSED, STRONG FOAM GLASS TILES."

2. I am familiar with the above-referenced patent application and the prosecution thereof before the U.S. Patent Office. I am also familiar with the Office Action dated September 11, 2006 issued therein. For the purposes of preparing this Declaration, I have reviewed the prior art references cited in the Office Action, including U.S. Patent No. 4,324,037 to Grady, II ("the Grady '037 Patent"), U.S. Patent No. 3,430,397 to Ellis ("the Ellis '397 Patent"), U.S. Patent No. 3,292,316 to Zeinetz ("the

Zeinetz '316 Patent"), U.S. Patent No. 4,450,656 to Lagendijk ("the Lagendijk '656 Patent"), U.S. Patent No. 4,124,365 to Williams et al. ("the Williams '365 Patent"), U.S. Patent No. 3,056,184 to Blaha ("the Blaha '184 Patent"), U.S. Patent No. 3,459,565 to Jones et al. ("the Jones '565 Patent"), U.S. Patent No. 3,592,619 to Elmer et al. ("the Elmer '619 Patent") and U.S. Patent No. 2,758,937 to Ford ("the Ford '937 Patent"). Based on my extensive academic and research experience as described below I am generally familiar with the field related to the above-mentioned prior art references and I believe that I am qualified as an expert in that field.

3. I received a Bachelor of Science degree in Physics from George Washington University in Washington D.C. in 1959, and received a Ph.D. in physics from The Catholic University in 1963. From 1963 to 1967, I was employed with the National Bureau of Standards, and afterwards I continue to be associated with the National Bureau of Standards as a consultant. In 1967, I joined the department of mechanics at The Catholic University of America as an associate professor. In 1970, I became a co-director of the Vitreous State Laboratory and also a professor of chemical engineering and material science at the same university. Currently, I continue to be the director of the Vitreous State Laboratory and am a professor of physics at the same university. The article in the Summer 2002 issue of the *CUA Magazine*, "Defending Against Environmental Disaster: CUA's Vitreous State Lab Has Answered the Nation's Call for 30 Years" by Richard Wilkinson, a copy of which is attached hereto as Exhibit 1, describes my contributions and achievements as a co-director of the Vitreous State Laboratory.

4. My primary area of expertise is in glass science research. In particular, I have developed technologies and products in the areas of fiber optics, defense fuels, and radioactive waste glass formulation. I have received over 43 patents in the United States and many more worldwide, and have been noted as "the area's leading individual inventor in number of patents granted" by the January/February 1990 issue of *Washington Business Journal Magazine*. For more details of my background and areas of expertise, please refer to my curriculum vita attached hereto as Exhibit 2.

5. Based on my review and understanding of all of the nine references relied upon by the Examiner (the Grady '037 Patent, the Ellis '397 Patent, the Zeinetz '316 Patent, the Lagendijk '656 Patent, the Williams '365 Patent, the Blaha '184 Patent, the Jones '565 Patent, the Elmer '619 Patent and the Ford '937 Patent) in the September 11, 2006 Office Action, I conclude that none of these references discloses or suggests, either individually or in any reasonable combination, a prestressed foam glass tile having <u>any</u> amount of prestress compression, let alone a prestressed foam glass tile having a <u>prestress compression of 4,000 psi or greater</u>, as required by all of the independent claims pending in this application, Claims 1, 23, 42 and 54.

6. By the Examiner's own admission, the first reference upon which he relies, the Grady '037 Patent, does not disclose a foam glass tile. *See* September 11, 2006 Office Action at 3. Similarly, the Examiner also acknowledges that the Ellis '397 Patent does not disclose a foam glass tile. *See id.* at 6. I agree. Based on my review and understanding of these two patents, neither the Grady '037 Patent nor the Ellis '397

Patent discloses or suggests a foam glass tile, let alone a prestressed foam glass tile having any amount of prestress compression.

7. On page 10 of the September 11, 2006 Office Action, the Examiner takes the position that "each of Lagendijk '656 and Zeinetz '316 does indeed, disclose prestressing of a foamed glass material as is set forth in the above rejection." I respectfully disagree. Based on my review and understanding of these two references, I conclude that neither reference teaches the prestressing of a foam glass tile under any amount of prestress compression, let alone a prestressed foam glass tile having a prestress compression of 4,000 psi or greater as required by all of the independent claims pending in this application, Claims 1, 23, 42 and 54, for the following reasons.

8. On page 3 of the September 11, 2006 Office Action, to support his position that the Zeinetz '316 Patent discloses prestressing of a foam glass material, the Examiner points to tension bars 36, 39 in FIG. 11 of the Zeinetz '316 Patent and asserts that these tension members hold foam glass tiles, citing Col. 4, lines 5-9 of the Patent. However, based on my review and understanding of the Zeinetz '316 Patent, FIG. 11 does not teach or even suggest the prestressing of a foam glass tile under any amount of prestress compression, contrary to the Examiner's assertion. The Zeinetz '316 Patent is directed to a roof structure, as shown in FIGS. 1 and 2 of the Patent. In conjunction with FIG. 5, the Zeinetz '316 Patent further teaches that the seam 19, 119, 21 and 121 is adapted to fit the abutting lateral edge portions of adjacent roof elements (*e.g.*, a1, a2, b2, c1, c2, and d in FIG. 5). *See* Zeinetz '316 Patent, Col. 3, lines 1-7. FIG. 11 illustrates the section of FIG. 5 along the line B--B and represents "coupling means" for abutting roof elements.

Id., Col. 2, lines 4-6 (emphasis added). In fact, the Zeinetz '316 Patent explicitly describes the tension bars 36 and 39 in FIG. 11 as "a locking means for use in connection with a U-shaped or tubular seam 19e, 119e, 21e and 121e." *Id.*, Col. 3, line 73 - Col. 4, line 4. In other words, the tension bars 36 and 39 in FIG. 11 are merely coupling or connecting means in conjunction with the U-shaped/tubular seam 19, 119, 21, 121 to keep adjacent roof elements together. I did not find any teaching or suggestion in the Zeinetz '316 Patent that the tension bars 36, 39 in FIG. 11 to which the Examiner points are the means for prestressing foam glass tiles, let alone providing prestress compression of 4,000 psi or greater.

9. During my review of the Zeinetz '316 Patent, I also noted that the reference teaches that the rows of interengaging profiles 19, 119, 21, 121 which keep each roof element in wedged engagement with the adjacent elements may render possible the "prestressing of the shell of the cupola." Zeinetz '316 Patent, Col. 3, lines 7-17. However, it was apparent to me that the term "prestressing" in "prestressing of the shell of the cupola" is different from the prestressing as applied to foam glass tiles to strengthen them in accordance with the present invention. For general reference providing the definition of "prestressing" as used in the context of the present invention, please refer to EDWARD G. NAWY, PRESTRESSED CONCRETE: A FUNDAMENTAL APPROACH 8-10 (1989), a copy of which is believed to have been submitted to the Examiner previously as part of the Information Disclosure Statement. To the contrary, in reading the Zeinetz '316 Patent, I understood the reference to "prestressing of the shell of the cupola" in the Zeinetz '316 Patent to be provision of a structural support to a

dome by keeping all the roofing elements together in wedged engagement, hence the title "self-supporting roof" for the Zeinetz '316 Patent. After a careful consideration of the teachings of the Zeinetz '316 Patent and based on my knowledge in the related field, I conclude that the "prestressing of the shell of the cupola" arising from wedged engagement of neighboring roof elements as suggested by the Zeinetz '316 Patent does not refer to the kind of prestressing applied to foam glass tiles as claimed in the present application. Furthermore, based on my knowledge and experience in the field, I find it hard to imagine a situation where the wedged engagement with neighboring elements as shown in the Zeinetz '316 Patent can provide a prestress compression of 4,000 psi or greater. Based on the foregoing considerations, I conclude that the Zeinetz '316 Patent does not teach or even suggest at all the prestressing of a foam glass tile under a prestress compression of any amount of prestress compression, let alone the claimed range of 4,000 psi and greater as required by all of the pending claims.

10. Moreover, the Zeinetz '316 Patent teaches a litany of roofing materials that could be used, including glass, wood, synthetic plastic, concrete, porous concrete, foamed plastic, foamed glass, cardboard, sheet metal, wool, cork and fiber board. These materials are used in a multi-layer structure where each layer is for a different purpose such as a "moisture-insulating layer" consisting of a "heat insulating layer," a "load sustaining layer" and a "sound absorbing layer." *See* Zeinetz '316 Patent, Col. 4, lines 8-15. The kind of layer that "foamed glass" may be used for is not taught. However, the load sustaining layer, which is the layer that would potentially be under compression, "is made of concrete, for example." *Id.*, Col. 4, line 14. In the Zeinetz '316 Patent, I find no

teaching that the load sustaining layer could be made of prestressed foam glass tiles as required by all the claims, let alone foam glass tiles having a prestress compression of 4,000 psi or greater as required by the rejected claims.

11. On pages 3 and 10 of the September 11, 2006 Office Action, to support his position that the Lagendijk '656 Patent discloses prestressing of a foam glass material, the Examiner points to the inner bracing cables 33, 34, the cross tie cables 36, the lower running cable 45, etc. that form the suspended roof structure in Figs. 1 and 2 of the Lagendijk '656 Patent as showing tension members holding foamed glass units in place, citing Col. 3, lines 30-60 and Col. 4, lines 34-37 as well as Fig. 6 of the Patent. I respectfully disagree. Based on my review and understanding of the Lagendijk '656 Patent, I conclude that none of the figures and text of the Lagendijk '656 Patent relied upon by the Examiner teaches or even suggests the prestressing of a foam glass tile under <u>any</u> amount of prestress compression, let alone a prestressed foam glass tile having a <u>prestress compression of 4,000 psi or greater</u> as required by all of the independent claims pending in this application, Claims 1, 23, 42 and 54, for the following reasons.

12. Like the Zeinetz '316 Patent, the Lagendijk '656 Patent is also directed to a roof structure, which, in the case of the Lagendijk '656 Patent, is composed of a wire mesh or netting with a sprayed polyurethane foam on top. *See* Lagendijk '656 Patent, Col. 4, lines 18-20. What the cited portion of Lagendijk '656 Patent suggests, at best, is the use of sprayed polyurethane foam (which is not a foam glass tile) or stiff elements of foam glass as a roof-covering material. *See* Lagendijk '656 Patent, Col. 4, lines 4-44. The

Examiner points to the inner bracing cables 33, 34, the cross tie cables 36, the lower running cable 45, etc. that form the suspended roof structure in Figs. 1 and 2 of the Lagendijk '656 Patent as showing "tension members," but I find no teaching, nor any suggestion, in the Lagendijk '656 Patent that those "tension members" contribute to prestressing of foam glass materials used as the roof covering materials under any amount of prestress compression. These alleged "tension members" form a part of a tensioned roof structure to which a fine mesh net is anchored. *See id.*, Col. 3, lines 47-54 ("This net or both nets, together with the post-tensioning of the roof structure, have been tensioned up to the final design tension, before at least a first layer of the roof covering is applied." (emphasis added)); *see also generally id.*, Col. 6, line 42 - Col. 8, line 14. The Lagendijk '656 Patent further teaches that the roof covering material is applied on this mesh net. *See id.*, Col. 4, lines 3-10. Hence, based on the foregoing description, I find it physically and technically impossible for the "tension members," the cable structure pointed by the Examiner, to provide any amount of prestress compression to the roof covering materials which are, according to the teaching of the Lagendijk '656 Patent, to stay above those "tension members" and are applied after the bars are tensioned, not before. *See* Lagendijk '656 Patent, Col. 9, lines 44-45.

13. Furthermore, Fig. 6 and Col. 9, lines 49-55 of the Lagendijk '656 Patent teach securing foam glass elements 65, which are used as part of the roof covering, to the glass-fibre mats 60, 61 by adhesive 66, thus providing an alternative means for reinforcing these foam glass materials and thereby teaching away from the prestressing as means for reinforcing these foam glass materials. By definition, this alternative

structure is again not prestressed since it is applied on top of the mesh net <u>after</u> the "tension members" are already in place and tensioned. I did not find any teaching or suggestion in the Lagendijk '656 Patent that the foam glass elements 65 amid the adhesive 66 shown in Fig. 6 be prestressed by any "tension members" such as the inner bracing cables 33, 34, the cross tie cables 36, the lower running cable 45, or any other component of the disclosed roof structure. Based on at least the foregoing reasons, I conclude that the Lagendijk '656 Patent does not teach or even suggest the prestressing of a foam glass tile under any amount of prestressing, let alone the prestress compression of 4,000 psi or greater.

14. Based on my review and understanding of the remaining references relied upon by the Examiner, I conclude that neither Williams '365 Patent, nor the Blaha '184 Patent, nor the Jones '565 Patent, nor the Elmer '619 Patent, nor the Ford '937 Patent teaches or suggests prestressing of a foam glass tile under any amount of prestress compression, let alone under prestress compression of 4,000 psi or greater.

15. Based on my review and understanding of all of the nine references relied upon by the Examiner (the Grady '037 Patent, the Ellis '397 Patent, the Zeinetz '316 Patent, the Lagendijk '656 Patent, the Williams '365 Patent, the Blaha '184 Patent, the Jones '565 Patent, the Elmer '619 Patent and the Ford '937 Patent) in the September 11, 2006 Office Action, I conclude that none of these references discloses or suggests, either individually or in any reasonable combination, a foam glass tile having a compression strength of 10,000 psi or greater prior to being prestressed as required by independent Claims 1 and 23 and their respective dependent claims. In particular, to support the

rejection of Claims 1, 5, 13, 14, 23, 27, 29-31 and 37, the Examiner takes the position that either the Williams '365 Patent or the Blaha '184 Patent suggests a foam glass tile having a compression strength of 10,000 psi or greater. *See* September 11, 2006 Office Action at 3. I respectfully disagree. Based on my review and understanding of the Williams '365 Patent and the Blaha '184 Patent, I came to a conclusion that neither reference teaches or suggests a foam glass tile having a compression strength within the claimed range of 10,000 psi or greater for the following reasons.

16. On page 3 of the September 11, 2006, to support his position that the Williams '365 suggests a foam glass tile having a compression strength within the claimed range of 10,000 psi and greater, the Examiner points to the following portion of the Williams '365 Patent: "Such a material should be readily available, easily formed in lengths up to 100 feet, be able to withstand a stress of <u>5,000-8,000 psi</u> . . ." Williams '365 Patent, Col. 1, lines 36-38 (emphasis added). However, this disclosed range falls short of and does not overlap at all with the claimed range of compression strength of a foam glass tile starting from 10,000 psi and higher as required by the rejected claims. Based on my knowledge and experience in the field, this difference in compression strength is substantial and the Williams '365 Patent does not explain how such substantial difference in compression strength can be overcome.

17. Moreover, Williams' '365 Patent does not even disclose "foam glass tiles," let alone "<u>prestressed</u> foam glass tiles" as required by the present claims. Indeed, the following portion of the Williams '365 Patent cited by the Examiner on page 11 of the September 11, 2006 Office Action in support of his position is the evidence: "<u>In such</u>

form, the foamed glass product can be used as a structural member in a number of industries including the housing industry as a bearing member . . . ." Williams '365 Patent, Col. 1, lines 19-22 (emphasis added). However, "such form" in the cited portion of the Williams '365 Patent refers to a "foamed glass" produced "in the form of elongate members, more particularly in the form of hollow elongate cylinders" as recited in the sentence in the Williams '365 Patent just before the cited portion. Hence, it is clear that the Williams '365 Patent is directed to an elongate structure of foam glass rather than foam glass tiles as in the present invention. In fact, the description of the preferred embodiment of the Williams '365 Patent is directed to production of foam glass in the form of hollow elongate cylinders so that it can be used as conduit such as sewer pipe, telephone pole, or power line. *See* Williams '365 Patent, Col. 1, lines 14-25 & FIG. 3. However, based on my knowledge and experience in the field, I find that, unlike in the case of foam glass tiles, prestressing of these foam glass hollow elongate cylinders to be used as conduit, telephone poles, etc. would not be desirable, nor is it technically feasible or economical. Based on at least the foregoing reasons, I came to a conclusion that the Williams '365 Patent does not teach or even suggest a foam glass tile having a compression strength within the claimed range of 10,000 psi and greater.

18. On page 3 of the September 11, 2006 Office Action, in support of his position that the Blaha '184 Patent suggests the claimed range of compression strength, the Examiner points to a portion in the Blaha '184 Patent disclosing a slab of cellular, agglomerated material having a compression strength "in excess of 1200 pounds per square inch." Blaha '184 Patent, Col. 3, lines 26-28. However, the compression strength

of 1,200 psi as disclosed by the Blaha '184 Patent falls far short of 10,000 psi, the lower end of the claimed range of compression strength required by the rejected claims. Furthermore, I do not find any teaching or suggestion of a foam glass tile having a compression strength of 10,000 psi or greater from a vague statement in the Blaha '184 Patent that the cellular material is to be "sufficiently strong to be used for structural purposes," on which the Examiner relies on page 11 of the September 11, 2006 Office Action to support his position. Blaha '184 Patent, Col. 1, lines 27-28. Even with my knowledge and experience in the field, I do not find that such a vague statement explains how a huge gap in compression strength of a foam glass tile between a mere 1,200 psi as disclosed by the Blaha '184 Patent and 10,000 psi or greater as required by the rejected claims can be technically overcome. Moreover, this statement does not teach that the resulting material can or should be prestressed. Simply put, the Blaha '184 Patent does not teach or suggest at all a foam glass tile having a compression strength within the claimed range of 10,000 psi or greater, let alone a <u>prestressed</u> foam glass tile with the claimed compression strength <u>and</u> prestress compression. Based on at least the foregoing reasons, I came to a conclusion that the Blaha '184 Patent does not teach or even suggest a foam glass tile having a compression strength within the claimed range of 10,000 psi and greater.

19. Contrary to any of the references cited by the Examiner in the September 11, 2006 Office Action, my co-pending application, U.S. Patent Application Serial No. 10/625,071, which has been incorporated by reference into the present application, actually describes the making of a foam glass tile having a previously unattainable

compression strength of 10,000 psi or greater. The properties of foam glass samples produced in accordance with the incorporated '071 Application are summarized in TABLE 1 in the present application. *See also infra* Pars. 26 & FIGS. 1-3.

20. Based on my knowledge and experience in the field, I understand the basic principle that by applying prestressing, the resulting compression strength of the prestressed product will decrease by the prestress amount while the resulting tension strength will increase by the same amount. I also understand that the optimum prestress level is defined in the field to be where a tension strength becomes comparable to a compression strength as the result of prestressing. In other words, the optimum prestress level is one half of the difference between the compression strength and the tension strength under non-prestressed condition. *See generally* EDWARD G. NAWY, PRESTRESSED CONCRETE: A FUNDAMENTAL APPROACH 8-13 (1989). Based on the foregoing, I calculated the optimum prestress level for the foam glass tiles described in TABLE 1 of the present application and found it to be approximately 44% of the compression strength of the foam glass tile prior to being in the prestressed condition. For example, for a foam glass tile having a compression strength of 10,000 psi prior to being in a prestressed condition, the corresponding optimum prestress compression is approximately 4,400 psi; for the one having a compressional strength of 12,500 psi prior to being in a prestressed condition, the corresponding optimum prestress compression is approximately 5,500 psi, etc.

21. As I concluded above, none of the references relied upon by the Examiner discloses the range of compression strength of a foam glass tile that reaches anywhere

near 10,000 psi. At best, the greatest amount of compression strength disclosed by the prior art is 8,000 psi, which is casually mentioned by the Williams '365 Patent, without any disclosure of how to go about achieving it, for an elongated tube, not a foam glass tile. For a foam glass tile having 8,000 psi, as I discussed above, the corresponding optimum prestress compression would be set at about 44% of 8,000 psi, or 3,500 psi. Based on the foregoing, I would expect that a prestress compression of 4,000 psi or greater would not be applied based on the compression strength disclosed by the prior art relied upon by the Examiner, including the Williams '365 Patent, as it would deviate from the optimum prestress level.

22. I also do not find credible the claim by the Williams '365 Patent that the elongated tube having a length of up to 100 feet and a compression strength of up to 8,000 psi should be readily available, which the Williams '365 Patent casually mentions without any support. *See* Williams '365 Patent, Col. 1, lines 14-25 and 36-38. Based on my long years of research experience and extensive knowledge in the field, such feat would be considered impossible even with today's foam glass technology, let alone in 1978, the issue date of the Williams '365 Patent. In fact, I did not find in the description of six examples in the Williams '365 Patent any indication of the success of such feat.

23. Based on my review and understanding of the Williams '365 Patent, I also find such claim by the Williams '365 Patent to be inconsistent with its later description of elongate foamed ceramic products made under the procedure it teaches. The elongate foamed ceramic product that the Williams '365 Patent teaches how to make has a cellular structure of closed, elongate bubbles with a diameter ranging from 0.01 mm to 1

cm and a length ranging from 2 mm to 5 cm. *See* Williams '365 Patent, Col. 2, lines 19-33. Based on my knowledge and experience in the field, while a small pore size by itself may not be a sufficient condition for a strong foam glass product (*see also infra* par. 25), it is a necessary condition and I doubt that a foam glass product having largest bubbles reaching 1 cm and 5 cm in diameter and length, respectively, could achieve a compression strength as high as 8,000 psi, let alone the claimed range of 10,000 psi or greater. I also note that none of the examples described by the Williams '365 Patent has an average pore size less than 1.0 mm. *See, e.g.,* Williams '365 Patent, Col. 6, lines 62-63 and Col. 8, lines 5-6. None of the examples provides any compression strength data, but based on the bubble sizes reported by the Williams '365 Patent, I doubt that any of the examples described in the Williams '365 Patent would be able to achieve a compression strength of 8,000 psi, let alone the claimed range of 10,000 psi and greater.

24. Based on my review and understanding of the Jones '565 Patent, the Elmer '619 Patent and the Ford '937 Patent, I conclude that none of these references, either individually or in combination with any other cited prior art, teaches that their disclosed pore sizes lead to a foam glass product strong enough for the purpose of prestress compression within the claimed range of independent Claims 42 and 54 and their respective dependent claims.

25. As shown in TABLE 1 of the present application and the incorporated '071 Application (*see supra* Par. 19), the present application teaches a way in which foam glass tiles having a pore size of less than 1.0 mm are strong enough to have the claimed compression strength prior to prestressing and the claimed prestress compression

required by the pending claims. However, the small pore size is a necessary but not, by itself alone, sufficient condition for the strong foam glass tiles strong enough for application of the claimed prestress compression. For example, even if its average pore size is small, the foam glass material may still have a low compression strength if the pores are dense and highly interconnected. In fact, the Jones '565 Patent discloses such a foam glass article having 18% open cells indicating a high degree of interconnectedness and a small compression strength of 129.6 psi. Jones '565 Patent, Col. 8, lines 72-75. The Elmer '619 Patent also focuses on "interconnecting pores" as the defining characteristics of its foam glass article. Jones '565 Patent, Col. 2, line 7. The Ford '937 Patent discloses a cellulated glass product having the specific gravity of 0.14 to 0.18, Ford '937 Patent, Col. 3, lines 22-24, which corresponds to a low density of 9 to 12 PCF. Such a low density cannot lead to a foam glass product strong enough for the purpose of prestress compression within the claimed range of 4,000 psi and greater. Neither the Jones '565 Patent, nor the Elmer '619 Patent, nor the Ford '937 Patent teaches or even suggests that the disclosed pore sizes lead to a foam glass product strong enough for the purpose of prestress compression of 4,000 psi or greater as required by the pending claims.

26. By way of comparison, the color photographs in FIGS. 1-3 below this paragraph show the cross sectional views of the un-prestressed foam glass tile samples made in accordance with the incorporated '071 Application. In fact, FIGS. 1-3 correspond respectively to Examples 5-7 in TABLE 1 of the present application. Once the corresponding samples were made, they were cut to take the measurements of various

properties, revealing the cross sectional views shown in FIGS. 1-3. FIG. 1 corresponds to a foam glass tile of Example 5 having an average pore size of 0.8 mm. The measured compression strength of Example 5 is 10,500 psi. Similarly, Example 6 shown in FIG. 2 has an average pore size of 0.6 mm. It achieves a compression strength of 12,500 psi. Example 7 shown in FIG. 3 has an average pore size of 0.3 mm and achieves a compression strength of 14,600 psi. All of these samples corresponding to FIGS. 1-3 are strong enough for a prestress compression within the claimed range of the pending claims (i.e., 4,000 psi or greater).

FIG. 1: Example 5 of Present Invention in TABLE 1

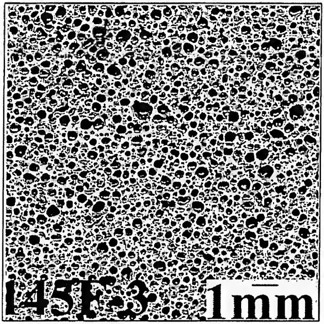


FIG. 2: Example 6 of Present Invention in TABLE 1

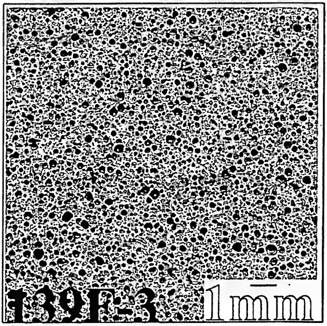
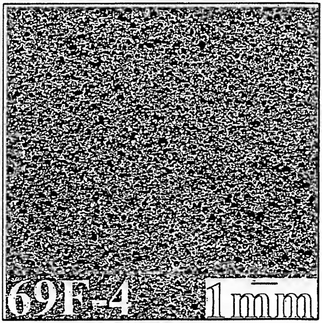


FIG. 3: Example 7 of Present Invention in TABLE 1



27. In summary, in my reading of the prior art references, at best, the Jones '565 Patent, the Elmer '619 Patent and the Ford '937 Patent merely teach that small pores can exist in foam glass materials. However, I did not find any teaching or even suggestion in any of these references that foam glass tiles made with small pore sizes in an appropriate manner can also have the compression and prestress strengths taught and claimed by in the present application.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: May 1, 2007

By: Pedro M Buarque de Macedo
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